DIGITAL VOLTMETER
LM 1867
& LM 1867C

SOLARTRON

TECHNICAL MANUAL

DIGITAL VOLTMETERS
LM 1867
& LM 1867 C

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SECTION 1
GENERAL

INTRODUCTION

The LM1867 is a six-window digital voltmeter with a maximum resolution of 1 part in 101999 and an accuracy of ±0.001% of full scale. Solid state digital circuits preceded by an electrometer input stage combine the advantages of 10μV sensitivity, 20msec conversion time, and 20 000 megohms input resistance. Diversity of application is provided by six alternative operating modes, scaling factor control, and comprehensive input filters. Facilities are also provided to permit the instrument to be referred to an external reference rather than the internal reference supply. Long-life neon indicator tubes are used in the display and a simultaneous binary coded decimal information facility is included.

LM1867C is a specially calibrated ±0.001% of full scale ±0.001% of reading version of the LM1867 and is supplied with a British Calibration Service certificate, quoting its final accuracy at the time of certification.

SPECIFICATION

Ranges

	Ranges	Sensitivity	Input R
1	1.00000 V	10μV	> 20 000 M
2	10.0000 V	100μV	> 20 000 M
3	100.000 V	1mV	10M ±0.1%
4	1000.00 V	10mV	10M ±0.1%

On all ranges the maximum reading is 101999.

Accuracy

Optimum Accuracy: The calibration should be checked daily. To realise optimum accuracy the instrument must remain at the temperature at which it was calibrated and should not be switched off between calibration and use.

At 20°C: Following calibration against an external standard on the range in use, the uncertainty is:

± 0.001% of full scale ± 0.003% of reading

LM 1867C
± 0.001% of full scale ± 0.001% of reading

Additional uncertainty when used on a range other than the one calibrated: ± 0.001% of reading. Also, on Range 1 only, a further uncertainty of ± 10μV exists due to internal noise.

At a constant temperature between 10°C and 30°C. At a temperature other than 20°C, following calibration against an external standard, there is an additional uncertainty. This is derived from the following table, which gives temperature coefficients in p.p.m. /°C for deviations from 20°C.

Range Calibrated	Range in use			
	1V	10V	100V	1 000V
1V	1	3	5	5
10V	3	1	3	3
100V	5	3	1	3
1 000V	5	3	3	1

Absolute Accuracy: The above accuracy figures are relative to the accuracy of the standard against which the calibration is performed. The voltmeter can be set up against an external Weston cell with a resolution of 0.001% without involving the use of external ratiometer facilities.

An unsaturated Weston reference cell is built in from which is derived a calibration voltage. On despatch from the factory this is set, at 20°C, with an uncertainty of:

± 0.002% absolute

LM 1867C: ± 0.001% absolute

In the ambient range 10°C to 30°C the temperature coefficient of this internal calibration voltage is:

< 5 p.p.m./°C (typically 2 p.p.m./°C)

Long Term Stability At normal ambient temperatures.

Internal Weston cell, for one year:

< −30 p.p.m. (typically −10 p.p.m.)

This can be compensated for as part of normal calibration against an external standard. The instrument can thus be used as an internal transfer standard.

Measuring circuits, for the first year:

± 30 p.p.m. typical

The drift in subsequent years will be considerably less than this. For optimum performance the instrument should be returned to Solartron for re-calibration at the end of the first year.

Factory Calibration All LM 1867 voltmeters are calibrated using the Solartron production standard which is housed in a temperature and humidity controlled calibration room. This standard is traceable to the National Physical Laboratory with an uncertainty of ± 7μV.

The LM 1867C receives a special check in the Solartron Standards Laboratory which is carried out by British Calibration Service approved engineers. This facility has both Ministry of Technology part III and B.C.S. approval, and the uncertainty of the volt referred to the N.P.L. is ±3μV. Each LM 1867C is supplied with a

B.C.S. certificate, which is an independent statement of final accuracy at the time of certification, and which may be renewed on payment of a calibration charge. It is recommended that re-certification is carried out annually.

Interference Rejection

Rejection performance is given as the ratio:

$$\frac{\text{Interference for 1 digit error}}{\text{Value of 1 digit}}$$

and is expressed in dBs. With AC interference the the r.m.s. value is used.

Series Mode: A switched filter gives the following rejections with main's derived interference,

50 Hz.	60 dB.
50 Hz.	80 dB.
50 Hz.	90 dB.
100 Hz.	90 dB.

Common Mode: The maximum permitted common-mode interference (input Lo to chassis) is 400V., peak or DC.

With 1kΩ unbalance between Hi and Lo leads:

DC > 100 dB.

Mains derived 50Hz. (with filter)

Ranges 1 and 2 > 70 dB.

Ranges 3 and 4 > 40 dB.

Settling Time The following times are required for a change of input to settle with error $< 0.01\%$

FILTER OUT	< 40 mSec.
60 dB.	< 400 mSec.
90 dB.	< 2.5 Sec.

Scale Factor Control By connecting suitable resistors to a rear socket the voltmeter may be scaled to read in arbitary units of load, pressure etc. This arrangement may also be used to increase the resolution.

Ratiometer External reference voltages can be used via an optional unit which plugs onto the rear panel. The reference units, which have an input resistance of 1kΩ per volt, are available for the following voltages:

EX 1626	± 100V.
EX 1627	± 20V.
EX 1628	± 10V.

Temperature This specification applies for ambient temperatures from 10°C to 30°C. No damage will result from operation in the range 0°C to 45°C. The instrument may be stored at temperatures between −10°C and 80°C, provided the Weston cell is first removed.

Maximum Sampling Rate 50/sec synchronised to mains frequency.

Operating Modes

(a) Continuous sampling with choice of resolution of 1, 2 or 5 digits. Push button can be used to hold reading.

(b) Manual sample by push button.

(c) External sample by contact closure or 4V positive pulse.

(d) Variable sampling rate down to 1 in 150 secs approx. in two ranges: (1) 0.02—5 secs
(2) 0.1—150 secs

(e) Maximum Reading—Instrument registers greatest positive excursion of input.

(f) Minimum reading—Instrument registers greatest negative excursion of input.

Display Neon indicator tubes, with a typical life of 20 000 hours, mounted behind a polaroid filter provide a display which is easy to read under all conditions of ambient light.

Decimal point is positioned automatically by the range switch.

Polarity Indication Automatic by + or − sign.

Print Out The displayed reading can be made available in parallel BCD form (1248 code) together with polarity and range information by fitting fan out unit type EX1869.
The fan out unit is housed in a compartment within the LM1867 and may be added to or removed from the rear of the instrument without removing the case.

Output Details Output information directly from LM1867 without fan out unit fitted:

	"1" State	"0" State
Polarity and Numeric	−20V	+10V
Range	0V	+50V

Maximum current 0.5mA

(See CAUTION in section 2, Print Out Information)

Output information from fan out unit:—

	"1" State	"0" State
Polarity, Range and Numeric	* −6V	0V

*at 5mA increasing to approx. −10V at zero current.

Remote Control Command signals are routed via the fan out unit, when fitted.

External Sample (Digitise Command)—contact closure or 4V positive pulse.

Conversion Complete (Print Command) −10V pulse into 1kΩ load.

Power Input 100—125V/200—250V 50Hz.55VA.

Overall Dimensions and Weight

BENCH UNIT: Height, including feet 8.3 in. (21.1 cm)
Width 19.6in. (49.8cm.)
Depth, excluding handles, 16.9 in. (42.9 cm)
Weight, 50 lb (22.8 kg)

RACK MOUNTED: Height, 7 in. (17.8 cm)
Width, 19 in. (48.3 cm)
Depth, excluding handles, 16.4 in. (41.7 cm)
Weight, 34 lb (15.5 kg)

SECTION 2

OPERATION

GENERAL

The instrument is supplied as a fully assembled and electrically set-up unit ready for installation. A signal lead terminated in wander plugs, and an external scaling resistance connection lead terminated in crocodile clips are provided with the instrument. One pair of rigid and one of flexible prods, two crocodile clips, and two spade connectors for attachment to the signal leads are also supplied.

CAUTION: Do not operate the instrument when it is standing on its back, on either side, or with the ventilation slots covered. In these conditions, air convection currents are impeded, and the voltmeter may sustain damage as a result of over-heating.

Preliminary Adjustments

(1) Set mains voltage selector panel in accordance with the declared voltage of the a.c. mains supply.

NOTE: The mains transformer has a split primary winding capable of parallel/series connection to accomodate mains inputs of 100, 105, 110, 115, 120, 125 and 200, 210, 220, 230, 240 and 250 volts.

(2) Check presence, continuity, and rating of mains fuse carried in holder on rear panel of instrument, 1.5. amperes SLO-BLO for 100-125 volts input, 750mA SLO-BLO for 200–250 volts input.

(3) Connect mains plug to mains lead, red to line (L) black to neutral (N) and green to earth (E). On instruments with mains leads in the international colours, connect brown to line (L), blue to neutral (N) and Green/Yellow to earth (E).

(4) Connect signal lead to the front or rear INPUT socket.

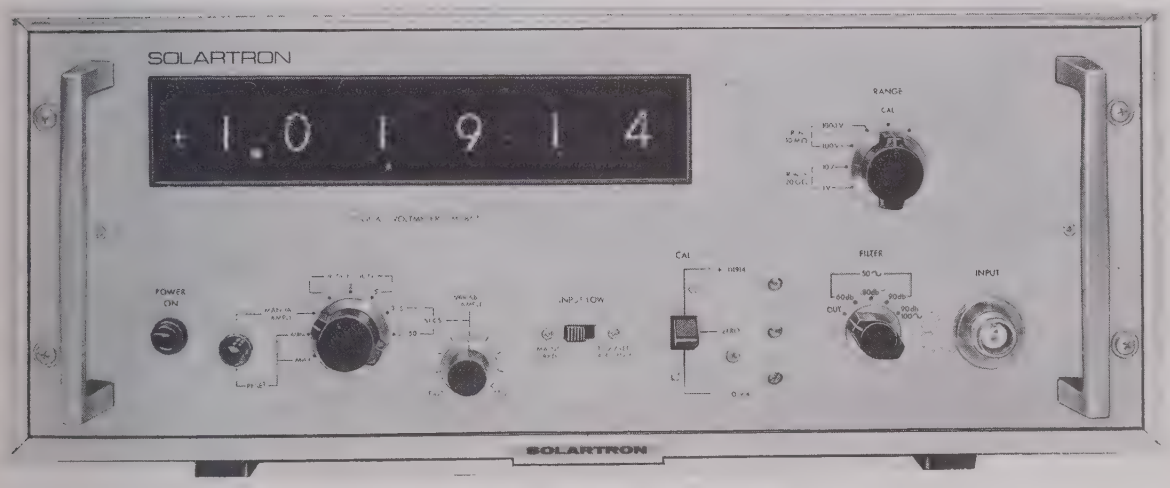


Fig.2.1. Front Panel LM1867

Front Panel Controls

RANGE Selector: A six-position switch giving choice of 1, 10, 100 or 1 000 volts full-scale in its first four positions. The fifth (CAL) position permits zero-setting and calibration against the internal standard cell. The sixth position is a spare one which can be used for conversion to a special range as an optional extra requirement. The instrument will normally read zero in this position.

MODE SELECTOR: An eight-position switch giving the following modes of operation:

MAX MIN	Instrument registers the greatest positive (MAX) or negative (MIN) excursion of the input voltage.
MANUAL SAMPLE	Single-shot conversion initiated by front panel push-button, external pulse application or remote contact closure.
RESOLUTION 1, 2, 5	Continuous sampling with the right-hand window moving in 1, 2 or 5 digit steps according to the control setting.
VARIABLE SAMPLE 0–5/0–150sec	Rate of sampling continuously variable in two ranges: (1) from 1 sample in .02sec. to 1 sample in 5sec. approximately. (2) from 1 sample in 0.1sec. to 1 sample in 150sec. approximately.

VARIABLE SAMPLE Potentiometer: A potentiometer giving continuous variation of sampling rate over either range provided by the mode selector in position 7 or 8.

FILTER Switch: A five-position selector, switching a twin T plus low pass filter to give a choice of 60, 80 or 90dB attenuation at 50Hz, or 90dB attenuation at 100Hz.

CAL Switch: A three-position, centre-biased, key-switch permitting zero-setting and calibration of positive and negative readings by adjustment of the three adjacent potentiometers.

MANUAL SAMPLE/RESET Push-Button:
A push-button switch performing three functions—
(1) Initiation of single-shot conversion on MANUAL SAMPLE operation.
(2) Instrument RESET on MAX. and MIN. reading operation.
(3) On continuous sampling operation, "freezes" reading as long as button is depressed.

INPUT LOW Switch:

A two-position slide switch—
(1) Connecting the black lead (input "low") of the signal input cable to MAINS EARTH or,
(2) Isolating the black lead for external earth or floating input operation.

INPUT Connector: A two-pole connector at which the voltage to be measured is applied via a twin-core screened cable. A made-up cable complete with a selection of push-on probes, is supplied for connection to this socket.

POWER ON switch: A toggle-switch applying the mains input to the mains transformer.

TILT STAND: A tilt stand is provided to enable the instrument to be angled to the optimum reading position.

REAR PANEL CONTROLS

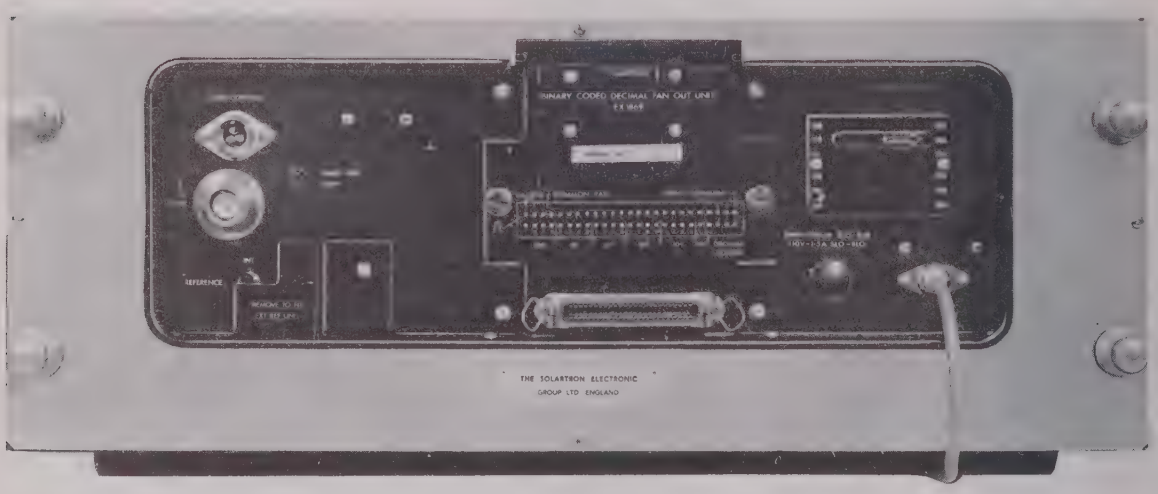


Fig.2.2. Rear Panel LM1867

INFORMATION OUT Connector: A blank plug-in chassis mounted in a compartment within the main frame of the voltmeter and accessible at the rear panel, incorporates a 50-way plug carrying information outlets of limited drive capability, and certain other services.

The chassis can be replaced by Fan-Out Unit EX1869 when outputs at increased power level in 1248 BCD code are required.

The facilities provided by the connector are :-

(1) Modified BCD outputs and range (decimal point) information.
(2) Polarity information.
(3) Print command signal.
(4) Remote initiation of a single-shot conversion by:— (a) remote contact closure, or (b) positive pulse application.

When working in the MAX. or MIN. reading mode, either operation (a) or (b) can be used to reset the voltmeter. The method of utilising the facilities provided by items (1), (2) and (3) is described in paragraph 'Information Out' and that for remote sample command (4) in paragraph 'External Sample'.

SCALE CONTROL Connector: A three-way socket for the connection of suitable external resistors to provide scale control. (Refer paragraphs 'Scale Control' and 'Selection and Fitting of Scale Control Resistors'). A lead is supplied for this purpose.

MAINS SELECTOR PANEL AND FUSE: A twelve-way selector for the mains transformer primary tappings.

INPUT Connector: A two-pole connector at which the voltage to be measured may be applied. The connector is wired in parallel with the front panel INPUT Connector.

REFERENCE SOCKETS: Two 4mm sockets for the insertion of an EXTernal Reference Unit when working with an external reference source or sources.

REFERENCE SELECTOR: A toggle-switch selecting the INTernal or EXTernal reference source.
NOTE: In normal (INT.) operation, the sockets are covered by a blanking plate, which also holds the REFERENCE selector in the INT. position.

INPUT REF. LOW Socket: A 4mm socket providing the common rail connection for the external reference source or sources.

Calibration

The instrument has excellent long-term stability and for normal laboratory use calibration should only be necessary once a day.
(1) Set POWER switch to ON and allow a warm-up period of 30 minutes.
NOTE: Though the voltmeter will attain an accuracy within .01% of its final reading after 5 minutes from switch-on, it is recommended that a warm-up period of at least 30 minutes be allowed before calibration.

(2) Set the RANGE selector to CAL. position, the mode switch to RESOLUTION 1, and the FILTER switch to OUT.

(3) With the key-switch in the ZERO (central) position, adjust the associated potentiometer to obtain a reading of "+00000".

(4) Slowly turn the potentiometer in a counter-clockwise direction until the reading just changes from "+00000" to "−00000". Do not advance the control beyond this point.

(5) Hold the key-switch in the upper position and adjust the associated potentiometer to obtain a positive CAL reading.

(6) Hold the key-switch in the lower position and repeat (5), adjusting the lower potentiometer to obtain a negative CAL reading.

(7) The instrument is now calibrated ready for operation.

Voltage Measurement

(1) Set the RANGE selector to an appropriate position. If the input voltage is unknown, set to the 1 000V range.
CAUTION: On the 1V and 10V ranges the input is connected directly to the grid of an electrometer valve and care must be taken to avoid excessive overload.

(2) Set the mode selector to the facility required, (normally RESOLUTION 1).

(3) Set the INPUT LOW selector as required by earthing arrangements. Whenever possible this should be MAINS EARTH. (Refer paragraphs "Input Earthing Arrangements").

(4) Connect the voltmeter input to voltage being measured.
CAUTION: When operating with the INPUT LOW selector in the MAINS EARTH position, the black signal lead is connected to mains earth, and care must be taken that this lead does not come into contact with any potential referenced to mains earth. Refer paragraphs headed "Input Earthing Arrangements".

(5) Read voltage off display, if necessary down-ranging to obtain greater sensitivity. The polarity indicated by the instrument is the polarity of the red input lead with respect to the black.

INPUT EARTHING ARRANGEMENTS

To obtain the greatest accuracy the "low" side of the input (black lead) should be connected to mains earth whenever possible. If the external circuit is not connected to mains earth, the INPUT LOW switch should be in the MAINS EARTH position to supply this connection.

If the external circuit is connected to mains earth, the INPUT LOW switch must always be set to the ISOLATED position, and the input low lead connected directly to mains earth externally. This arrangement provides earthing at only one point, thus avoiding inaccuracies which can occur due to earth loops.

MEASUREMENTS MAY BE MADE with the input "low" (black lead) not connected to mains earth, in which condition the black lead may be "floated" up to ±400 volts from mains earth. Before connecting the black lead to any potential referenced to mains earth, the INPUT LOW switch must be set to the ISOLATED position. If the connection is made with the INPUT LOW switch set to MAINS earth an excessive current may flow.
NOTE: A 10 ohms resistor, mounted on the rear of the INPUT LOW switch, is wired in the input "low"/mains earth line to act as a fuse minimising the damage caused by such an overload. Should this protective resistor become "open circuit", the voltmeter will be permanently "floating", and will exhibit a zero error identical with that described in paragraph "Two points regarding accuracy under floating conditions should be noted". If, following the method also described in the same paragraph, it is established that a zero error is present, the continuity of the resistor should be checked, and a replacement fitted if found necessary.

TWO POINTS REGARDING ACCURACY UNDER FLOATING CONDITIONS should be noted:
(1) The accuracy may be affected by the insulation resistance of the voltmeter between input "low" and mains earth. This is typically 400 megohms.

(2) If the input filter is switched out, small zero errors may occur, particularly on the 1V and 100V ranges.

A 0.47μF capacitor is connected between mains earth and common rail to minimise these latter errors.

They can, however, be eliminated by setting the FILTER switch to any position other than OUT. If it is desired to operate the instrument in the "floating" condition with no filtering applied, the extent of the zero error can be found by short-circuiting the input, and applying appropriate correction to subsequent measurements.

INPUTS WITH HIGH NOISE CONTENT

A comprehensive low-pass filter is provided to permit measurement of signals having a high noise content. Other facilities which can be usefully employed with such signals are:

(1) reduction of sensitivity by the RESOLUTION control,
(2) holding the reading by depression of the MANUAL SAMPLE/RESET push-button,
(3) slow-rate VARIABLE SAMPLING using the 0–5sec. range.

The presence of noise can be confirmed by checking that the reading changes when the filter is switched in and out. If the reading varies from one filter position to another the position of higher attenuation should be used. The characteristics of a typical filter are shown graphically in Fig.2.3.

Note: When using an LM1867C in the presence of noise, it may not be possible to achieve the full specified accuracy unless the filter is switched in.

The 90dB–100Hz position is provided for use with signals having a high 100Hz ripple. It can also be used to measure the average value of any full-wave rectified 50Hz mains voltage. The approximate values of 50Hz input ripple causing an error of one digit on the 10V range are:

60dB position	200mV peak-to-peak
80dB position	2V peak-to-peak
90dB position	6V peak-to-peak

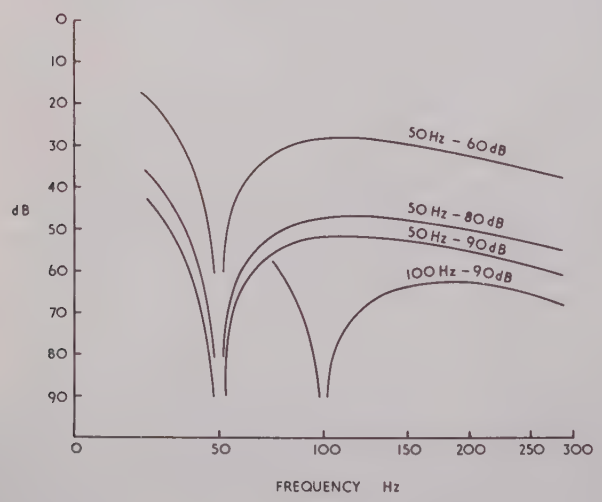


Fig.2.3. Typical Filter Characteristic

Maximum and Minimum Reading Facility

In the MAX. position, the instrument will read and hold displayed the greatest positive excursion of a slowly varying signal. In the MIN. position, the instrument will read and hold displayed the greatest negative excursion.

Provided that the input voltage remains at its maximum or minimum value for at least 20msec., the correct reading will always be displayed. If this condition is not fulfilled the correct maximum or minimum value will only be displayed if the input reaches its maximum or minimum at least once about the point marked "X" in Fig.3.2. The voltmeter can be reset by depression of the MANUAL SAMPLE/RESET pushbutton or the application of an external sample command (Refer to paragraph headed "External Sample").

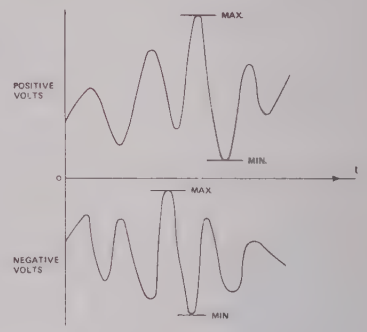


Fig.2.4. Maximum and Minimum Readings

Variable Sample Operation

The rate of sampling can be continuously varied by the VARIABLE SAMPLE potentiometer over two ranges selected by the Mode Selector.

Range 1: 0–5sec from 1 sample in .02sec to 1 sample in 5sec approximately.
Range 2: 0–150sec from 1 sample in 0.1sec to 1 sample in 150sec approximately.

An approximation to the sampling rate can be assessed from the divisions marked on the front panel. A more exact result can be obtained by using a varying input and timing the intervals at which a change in reading occurs.

CAUTION: The filter should be used with caution when on variable sample operation since the first sample reading after an input voltage change will be incorrect by an amount proportional to this change. For example, on the 10V range an input change of 1 Volt will give approximately a 12 digit error on the first sample; the second sample will be correct.

RATIOMETER OPERATION

The instrument can be used for ratiometer operation when set-up against external reference supplies. In this mode of operation, the value of the input signal is presented as a ratio of the reference voltage. Direct reading of true ratios will naturally only be obtained when the reference supplies have a value of ±100 or

±10 volts. Direct ratio reading with respect to ±20 volts, can be provided by a suitable external attenuator arranged to reduce the voltages applied to the input of the External Reference Unit to ±10 volts.

External Reference Operation

General

Three types of External Reference Unit are available to accommodate reference sources of different levels, viz:—

EX1626	±100V Reference Supplies
EX1627	±20V Reference Supplies
EX1628	±10V Reference Supplies

Installation

All External Reference Units are identical in size and physical construction.

(1) Withdraw screw securing blanking plate to the rear panel of the voltmeter, and remove blanking plate.

(2) Fit the External Reference Unit into the two sockets exposed by removal of the blanking plate, and secure unit by tightening the captive screw.

(3) Connect the external reference supplies to the 4mm sockets on the Reference Unit, observing polarity. The zero volts reference point of the reference supplies must be connected to the INPUT REF LOW socket on the rear panel of the voltmeter.

(4) Set the REFERENCE selector to the EXT Position.

Fig.2.5. External Reference Unit

Setting-Up Procedure

NOTE

Since when operating with external reference supplies, the zero volts reference of these sources is connected to the voltmeter common rail at the INPUT REF LOW socket the black (input "low") lead of the signal input cable must not be used for this purpose. Failure to observe this precaution will result in the creation of earth loops and their associated errors. It is therefore recommended that when working with external reference sources, the black input lead is taped back to the cable insulation.

(1) Set the voltmeter RANGE selector to that position appropriate to the voltage of the reference supplies being used.

(2) Set the mode switch to RESOLUTION 1, and the FILTER switch OUT.

(3) Connect the red input lead to the zero volts reference point of the reference supplies.

(4) Adjust the ZERO potentiometer to obtain a reading of "+00000".

(5) Slowly turn the potentiometer in a counter-clockwise direction until the reading just changes from "+00000" to "−00000". Do not advance the control beyond this point.

(6) Disconnect the red input lead from the zero volts reference and apply it to the positive external reference source.

(7) Adjust the +VE CAL. potentiometer to obtain a reading equal to the voltage of the positive reference supply in use, viz., +100.000, +20.000, or +10.0000V.

(8) Adjust the −VE CAL. potentiometer to obtain a reading equal to the voltage of the negative reference supply in use, viz., −100.000, −20.000, or −10.0000V.

(9) The instrument is now set-up for use as a bi-polar digital voltmeter, referenced to the external sources.

NOTE

The preceding method of calibration is recommended for applications in which the voltmeter is to be used exclusively with external reference sources. For applications in which it may be required to switch between internal and external reference working, it is initially preferable to calibrate the voltmeter against the external reference sources by adjustment of the pre-set variable resistors provided on the External Reference Unit, and thereafter make the final calibration adjustment on the voltmeter front panel. This method has the advantage that when reverting to internal reference working, only fractional adjustment of the internal calibration control will be necessary to standardise the voltmeter against the internal standard cell.

PRINT OUT INFORMATION

Modified BCD outputs, decimal point information polarity and print command signals are extended to an internal 50-way socket SKA. Connections to the socket are made via the engaging plug PLA mounted on a blank chassis, which is carried in a compartment within the main frame of the voltmeter. The blank chassis can be withdrawn from its housing in the main frame after loosening the two captive securing screws in the middle of the rear panel. The connecting cableform is then led through the circular aperture cut in the back-plate of the blank chassis, and the individual leads soldered to the appropriate pins on the plug. Finally the blank chassis is returned to its compartment within the main frame of the voltmeter, and secured in place with the two captive screws. The voltage levels of the various outputs are given

in the specification. The maximum load current available for driving external devices is limited to 0.5mA "on" for the binary and polarity outputs, and 0.3mA "on" for the decimal point outputs. If greater drive power is required, fan-out unit (EX1869) delivering 5mA, must be fitted.

NOTE: If the information outlets are used without the Fan-Out Unit, each binary and polarity output line must have a resistor inserted in it of at least 27 000 ohms. A voltage level changing network is required for the decimal point outputs, utilising two 100 000 ohms resistors for each signal, one resistor going to a −30 volt supply and the other to the signal source. The free ends of each pair are connected together to give the output.

CAUTION: Since they are derived from the collectors of the quantity bistables, the information outlets are not updated by the digital carry logic. Hence, without the Fan Out Unit, the output information bears no simple relationship to the display.

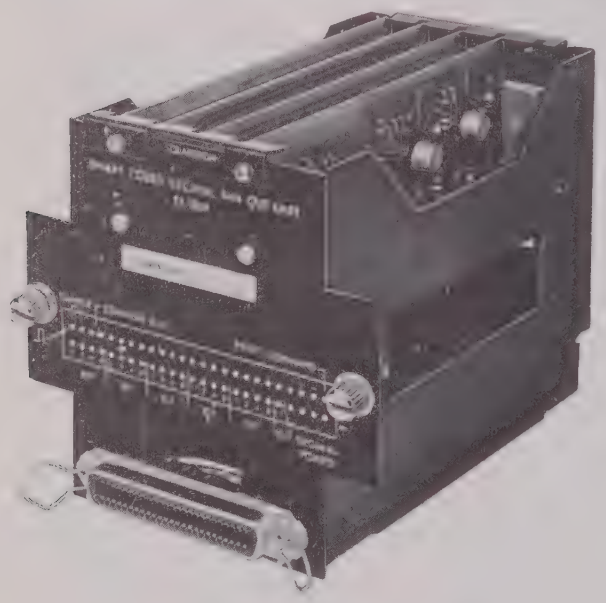


Fig.2.6. Fan Out Unit EX1869

EXTERNAL SAMPLE

Two pins (Nos. 1 and 27) are provided on the 50-way socket SKA to permit a single-shot conversion to be initiated by:—

(1) Closure of remote contacts connected across pins 1 and 27, or
(2) A positive pulse of 4 volts amplitude applied across pins 27 and 28 (common rail).

NOTE: When the instrument is operated in the MAX. or MIN. reading mode, either operation described in (1) and (2) preceding can be used to reset the voltmeter.

The 20msec. conversion time is synchronised to mains frequency, and the following conditions must be met for correct operation from a random external command signal.

(1) The input voltage must be present for at least 12msec before the sample command is delivered.

(2) The input voltage must persist for at least 20msec after the sample command is delivered.

If consecutive input voltages vary widely in amplitude and polarity, the input should be applied 60msec before the sample command signal.

SCALE CONTROL

Applications

Scale control is achieved by connecting suitably valued resistors externally at the rear panel SCALE control socket. Since these resistors are in effect scale multipliers their inclusion will always increase the instrument reading. This facility has three principal uses:

(1) To provide an increase in resolution up to 1 part in 100 000. For example, with an input just in excess of 1V, the maximum resolution normally attainable is approximately 1 in 10 000. The connection of an external scaling resistor will multiply the reading approximately 8 times to give an improved resolution of the order of 1 in 80 000.

(2) To alter the scale as necessary to permit the direct measurement in units other than those of voltage. For example, assume that the 10V range of the voltmeter is being used for temperature measurement in conjunction with an iron/constantan thermocouple developing 54μV/^{o}C. Since this range has a digit sensitivity of 100μV, the displayed reading will approximate to one-half the correct reading in ^{o}C. The connection of an external resistor to double the reading will enable the instrument to read directly in degrees.

(3) To alter the scale to obtain a convenient full-scale reading which will facilitate linearity checks. For example, it may be required to check the linearity of a transducer developing an output of 7.995 volts at full-scale. This is an inconvenient reading and the check would be simplified by the inclusion of an external resistance to increase the instrument's full-scale reading to 10.0000.

Selection and Fitting of Scale Control Resistors

The external scaling resistance is connected to the SCALE CONTROL socket via the lead supplied. The lead must not be run in close proximity to any source of mains hum, since one side of it connects to a highly sensitive point in the voltmeter. The value of external resistance required for a given scaling factor is dependent on the output resistance of the voltmeter potentiometer circuit. This is nominally 37.509k ohms, but may vary by ±0.05% in different instruments according to the settings of certain preset controls. The approximate values of scaling resistors required to give X2 to X9 multiplication factors are listed in Table 2.1.

The exact value of resistance necessary for any given multiplication factor can be determined by setting-up a convenient reading on the instrument, connecting the external scaling resistance, and adjusting its value until

the new reading is the required multiple of the original reading. The type of resistors used for scaling must be chosen having regard to the application. For general short-term operations, cracked carbon resistors are suitable, but for long-term checks, particularly where a high multiplication factor is being used, small changes in resistance will affect the reading and it is recommended that precision wire-wound resistors of low temperature coefficient (.002% per ^{o}C) are used. The highest multiplication factor which can be usefully employed is limited by the inherent noise generated in the input amplifier. This level is such that above X9 or X10 multiplication, it becomes increasingly difficult to obtain completely steady readings. For the same reason, scale control cannot generally be used on the 1V range where the digit sensitivity is already 10μV.

Multiplication Factor	Approx. Resistance Value Ohms
X2	33.34k
X3	14.58k
X4	8.33k
X5	5.21k
X6	3.33k
X7	2.08k
X8	1.19k
X9	530
X10	0

Table 2.1 External Scaling Resistors

INPUT CONDITIONS

The conditions present on the ends of the input leads with no filtering applied are shown in Fig.2.7. Input cable capacitance contributes largely on the 130pF input capacitance. The input capacitance as measured directly on the INPUT socket is 10pF.

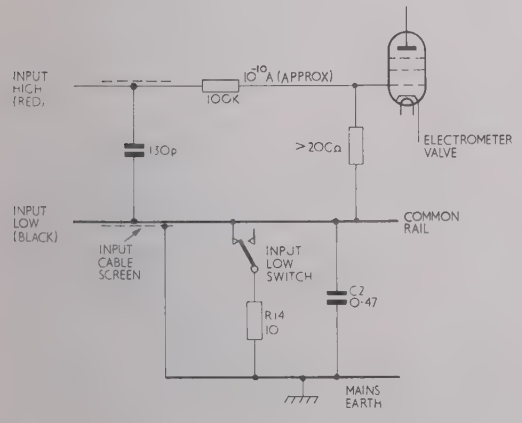


Fig.2.7. Input Conditions

SECTION 3

TECHNICAL DESCRIPTION

PRINCIPLES OF OPERATION

General

Basically, the voltmeter is a successive approximation analogue to digital converter in which the input is balanced against an incremental comparison signal made up from the sum of selected reference signals of decreasing value. If the selection of a reference signal causes the comparison signal to exceed the input the reference signal is rejected; otherwise it is retained in the comparison signal. In either event, the next reference signal is tested and the procedure is repeated until the least significant reference signal [one bit] has been tested. The comparison signal then equals the input to within one bit and a digital measure of the input is provided by those reference signals which have been selected.

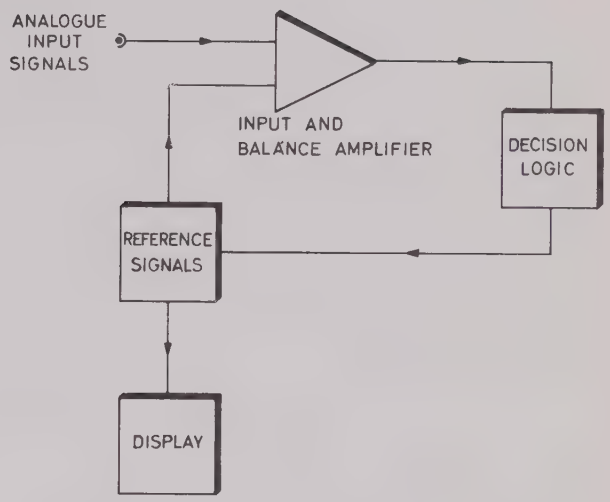


Fig. 3.1 Principle of Operation

Simplified Operational Principles

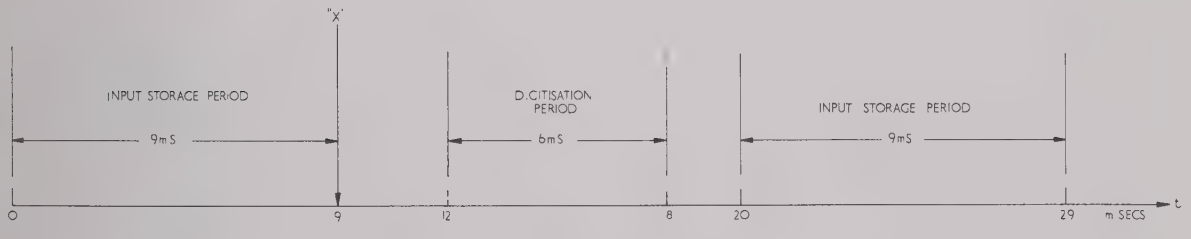


Fig. 3.2 Operational Sequence

The input voltage is sampled 50 times each second, i.e. once every 20msec. Each sampling period has an input storage period of 9msec, a 3msec, rest period, a 6msec digitisation period and a further 2msec. rest period, as shown in Fig. 3.2. For the duration of the input storage period, the input voltage is applied via the contact of RLA [one of two synchronous chopper relays, RLA and RLB, operating at mains frequency] to the valve differential amplifier stage of the input amplifier, Fig. 3.3. During this period, capacitor C is connected in the amplifier loop via contact RLB and is thereby charged to a potential effectively equal to the input voltage. At the end of the input storage period, both relay contacts change over and approximately 3msec. later, digitisation commences. This occupies 6msec. during which time the instrument goes through a balancing process so that at the end of the period a voltage is present on V1 grid which balances the voltage held by C on V2 grid. At the end of the digitisation period the instrument displays the reading. Following the digitisation period, a further rest period of 2msec. is allowed before the sequence is repeated.

The various timing periods are shown in Fig. 3.4. It is important to realise that the voltage held on capacitor C is the voltage present at the instant when the relay contacts change over at the end of the input storage period. Thus, if the input is varying slowly, the reading displayed by the instrument will be dependent on the voltage present at time "X" in Fig. 3.2.

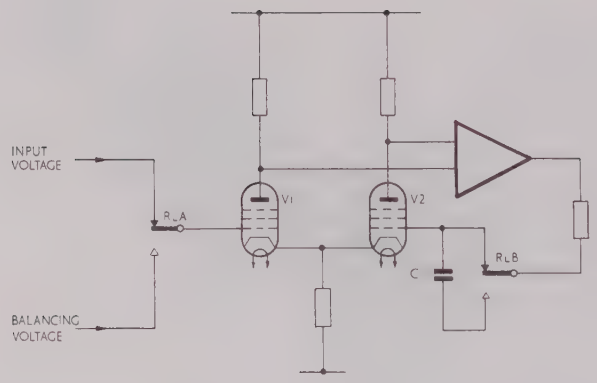


Fig. 3.3 Input Circuits

DETAILED OPERATIONAL PRINCIPLES

Input Circuits

The input voltage is taken through a range switch and, on the upper ranges, through an attenuator to the balance amplifier. The range switch can also be positioned to accept the output from a standard Weston Cell for calibration purposes.

Balance Amplifier

The balance amplifier consists of a high gain, drift-corrected d.c. chopper amplifier. Its input stage employs a cathode coupled differential amplifier, the input grid of which is switched at mains frequency between the signal input [drift-correct period] and the incremental reference voltage [digitising period] by contact RLA/1 of chopper relay RLA. During the drift-correct period, the output voltage of the balance amplifier is fed back to the second grid of the input stage via contact RLB/1 of a second chopper relay RLB, so that a voltage equal to the sum of the input and drift voltages is stored on capacitor C. The stored voltage will be of the same polarity as the signal input. During the digitising period, the effective input to the balance amplifier can be considered as being the algebraic sum of the reference voltage input and the voltage held in capacitor C. The resultant error signal appearing at the output of the balance amplifier is applied as a control voltage to the decision logic circuits.

Comparison Circuits

Start Circuitry

The signal which starts the sequence of operations is switched by the gate controlled by one of three sources according to the selected mode of operation. These sources are:-

[i] the balance amplifier output [MAXIMUM, MINIMUM and RESOLUTION 1, 2, 5 operation].

[ii] the sample bistable [MANUAL SAMPLE operation].

[iii] the ramp voltage generated by an RC charging circuit [VARIABLE SAMPLE operation].

In all cases, the start gate, when opened, delivers a negative going pulse synchronised to mains frequency. This pulse is used to turn over the ring start bistable, which in turn:-

[i] switches on a 4kHz clock oscillator to initiate the ring cycle, and

[ii] steps a ring counter to its first [polarity] stage.

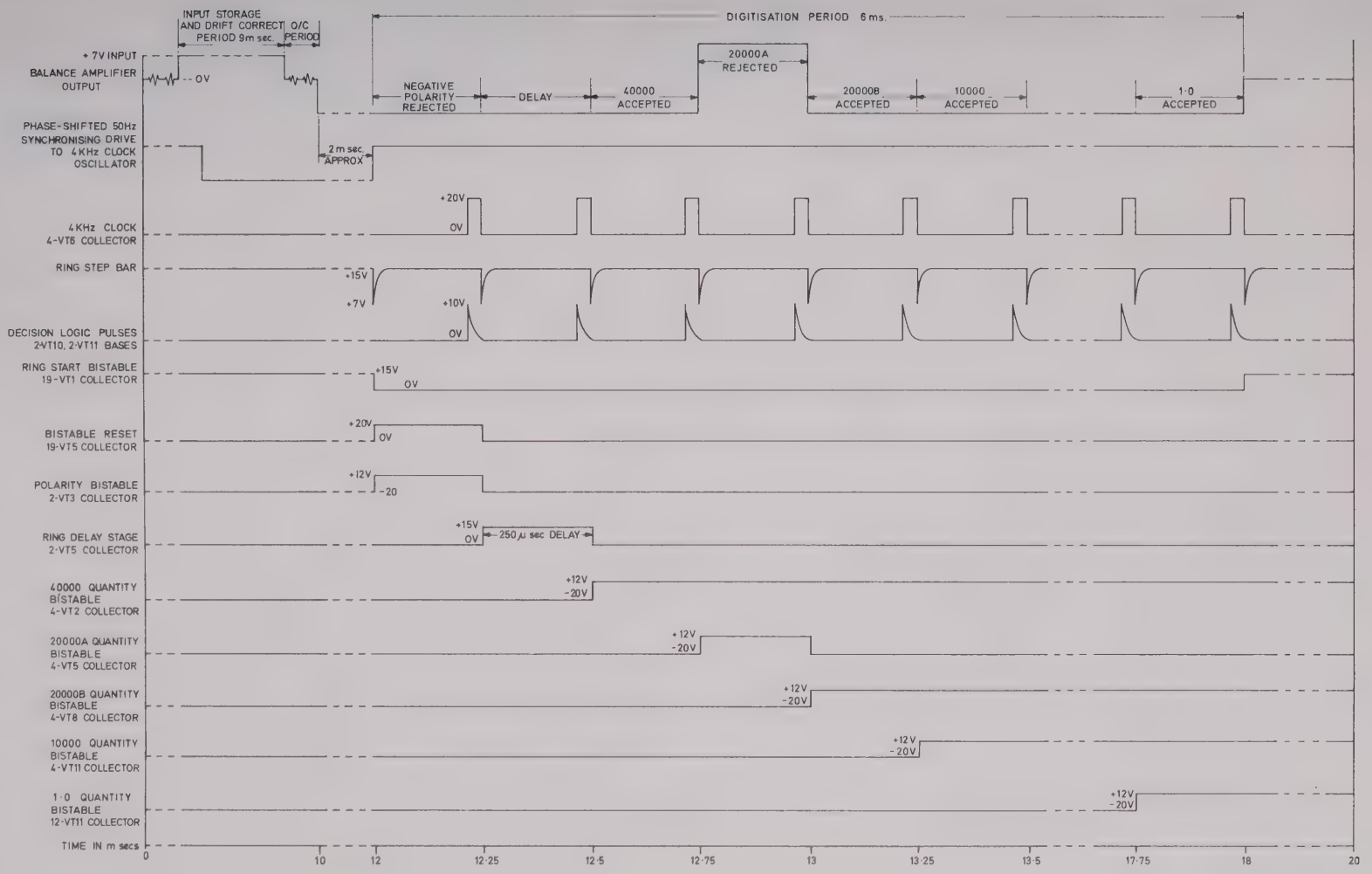


Fig. 3.4 Timing Waveforms

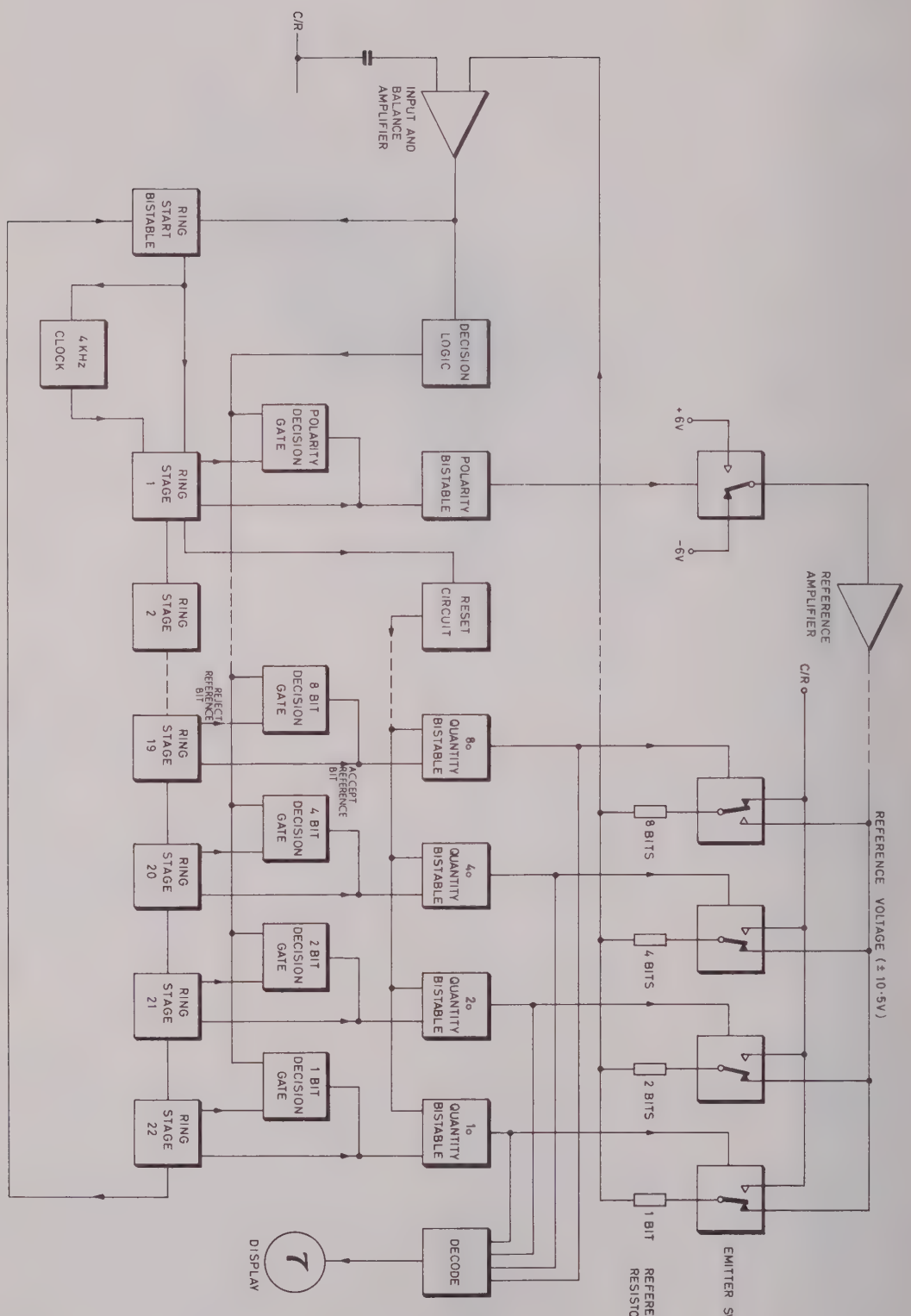


Fig. 3.5 General Block Schematic Diagram

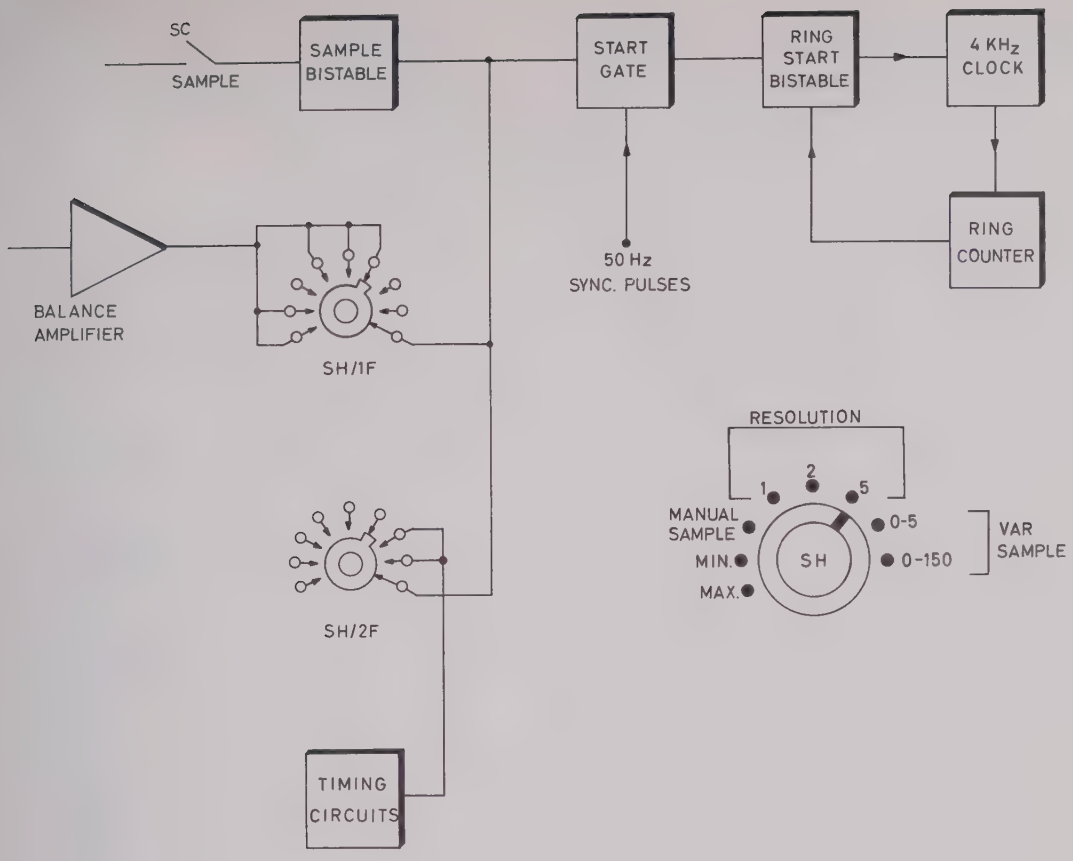


Fig. 3.6 Start Circuitry

4kHz Clock Oscillator

The output from a free running 4kHz oscillator is employed to trigger the decision logic circuits and to step a twenty two stage ring counter.

The oscillator has a mark-space ratio of 8 : 1 and its output is differentiated to provide negative and positive going pulses at 250μsec. intervals. The negative going pulses are used to drive the ring counter and the positive going pulses, [which lag the negative going pulses by approximately 220μsec], trigger decision logic circuits operating a gate control circuit.

Ring Counter

The ring counter controls circuits which connect a reference supply via precision resistors to the balance amplifier. The ring counter stages, in order of stepping are shown in Table 3.1.

Table 3.1 Ring Counter Stages

RING STAGE		SIGNIFICANCE
[1]	Polarity	
[2]	Delay	
[3]	40 000 Units	10000's Decade (10^4)
[4]	20 000 A Units	
[5]	20 000 B Units	
[6]	10 000 Units	
[7]	8 000 Units	1000's Decade (10^3)
[8]	4 000 Units	
[9]	2 000 Units	
[10]	1 000 Units	
[11]	800 Units	100's Decade (10^2)
[12]	400 Units	
[13]	200 Units	
[14]	100 Units	
[15]	80 Units	10's Decade (10^1)
[16]	40 Units	
[17]	20 Units	
[18]	10 Units	
[19]	8 Units	1's Decade (10^0)
[20]	4 Units	
[21]	2 Units	
[22]	1 Unit	

Polarity Decision

The first negative pulse from the clock oscillator causes the polarity bistable to change state and set to the condition required for a negative polarity input signal. At the same instant, a positive reset signal is applied to all quantity bistables to return them to the off condition. The differential inputs to the balance amplifier now consist of common rail potential [the quantity bistables connect the reference resistors to common rail via emitter switches] and the voltage stored on capacitor C, this voltage being of the same polarity and magnitude as the signal input. If this voltage is of negative polarity, then the polarity bistable must be held in its existing state. If of positive polarity, the bistable must be returned to its other condition. The state which the polarity bistable finally assumes is determined by the polarity of the balance amplifier output signal, which is applied to the decision logic. If the polarity of the signal input is negative the second negative clock pulse is gated out and does not reset the polarity bistable. If the polarity of the input signal is positive, the pulse is passed to the polarity bistable which is thereby turned over to its other condition.

Reference Supplies

Outputs are taken from the polarity bistable to emitter switches which select the positive or negative reference as required [negative source for positive input signal or vice versa]. The selected source of reference voltage is derived from an oven-referenced zener and is applied to a reference amplifier which delivers the $\pm$ 10.5 volts stable supply. The polarity decision, when taken, holds for the duration of one ring cycle.

The second negative clock pulse also cuts on a ring delay stage. The function of this stage is to provide a 250μsec rest period to give the reference amplifier time to settle after the polarity switching.

Quantity Decisions

The third negative pulse steps the ring to the 40 000 stage and the associated bistable turns over to connect the first reference resistor to the reference supply to apply 40 000 units of reference voltage to the balance amplifier via relay contact RLA/6. The polarity of the balance amplifier output now depends on the relative magnitude of the reference signal and the voltage stored on capacitor C. If the former is equal to or less than the latter, the polarity of the signal at the output of the balance amplifier will remain unchanged. If, however, the reference voltage is greater than the stored voltage, the polarity of the amplifier output signal will be reversed. The balance amplifier output signal polarity is now employed to operate circuits which either accept or reject the reference voltage, as appropriate.

Succeeding clock pulses to the ring counter connect reference resistors associated with the remaining stages, listed in Table 3.1, to the reference supply. For each stage, a comparison process, identical to that for the 40 000 stage, takes place, until the applied reference voltage balances the input signal stored on capacitor C. When all ring stages have been stepped, the ring returns to its initial state to await a further start signal and the bistables remain set up to read the digital value of the input signal.

All stages, except the most significant, present by means of their associated bistables, 1248 BCD signals on five decades. To ensure that the tens and units decades cannot each exceed a count of 9, veto circuits are incorporated which lock out the 40 and 20 or 4 and 2 units of reference if 80 or 8 units respectively are accepted. The thousands and hundreds decades are both limited to counts of 11, veto circuits ensuring 4 000 or 400 is locked out if 8 000 or 800 is accepted.

The ten thousand stage gives an output in 1224 BCD form, the 20 000B units being vetoed if 40 000 or 20 000A units is rejected. A gating circuit detects when 100 000 or more units have been accepted and carries this information forward to the most significant stage where the maximum display is 1 digit. All decade outputs are decoded to decimal form to drive display tubes and are also made available in modified BCD form for print out purposes.

Polarity Indication

The polarity indication lamps are fitted to an annunciator panel at the front of the instrument. The neon ILP7, which illuminates the negative sign, remains on until overridden by the neon illuminating the positive sign, ILP8. Operation is controlled by the polarity bistable on board No. 2.

Digital Carry Technique

One of the major causes of inaccuracies in successive approximation voltmeters is miscounting due to overloading of the input amplifier. The digital carry logic eliminates miscounting and allows the range to be extended to 99999 and accuracy improved to $\pm$ 0.001%. If a conventional five window voltmeter with a nominal full house of 99999 were used to measure an input of 79997, then the sequence shown in Fig. 3.7 could take place.

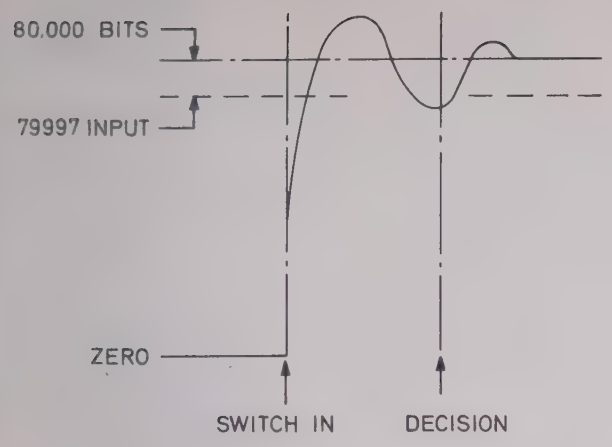


Fig. 3.7 Decision Sequence

The first ring position switches in a reference of 80 000 bits. This will be applied to the balance amplifier where due to stray capacitance, settling time and amplifier overloading, the reference reaches its final value in the manner shown. The decision to accept or reject the reference could be made at a time when it has fallen below the value of the input applied to the voltmeter and the 80 000 bits will therefore be accepted. Before trying the next reference of 40 000 bits, the system settles and each subsequent reference will be rejected. Hence the voltmeter will indicate a reading of 80000 although the input is only 79997. Under these circumstances, the voltmeter will indicate 80000 for all inputs between 79997 and 80000 but will read correctly if the input exceeds 80000.

If the input were 80005 as in Fig. 3.8 then the amplifier may signal "too much" and cause the 80 000 bit reference to be rejected. In this case, all subsequent references will be accepted and the voltmeter will indicate 79999 until the input exceeds 80005.

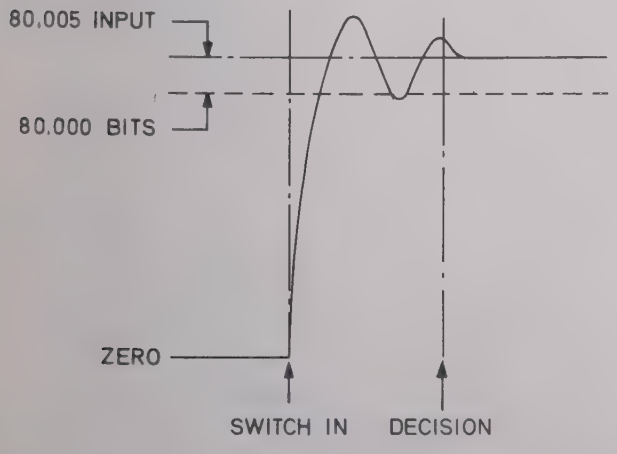


Fig. 3.8 Decision Sequence

The digital carry method acknowle ges that there may be errors in the most significant decades at the time of decision. These errors are made up by adding additional increments in lower decades and carrying this information forward as follows. The most significant decade uses a code 1224, the others being 1248. This means that the first choice need be 1 part in 40 000, instead of 1 part in 80 000. While trying the increments in this decade, and those in the second decade, the reference supply is biased to give increments which are greater than nominal. By doing this the 40 000 choice [the first] will be rejected for inputs which are several bits in excess of 40 000 - the exact figure does not matter, and will depend on the settling characteristics of individual instruments.

When trying the next decade the major choice[s] will have settled. If the input is in excess of 40 000, the amplifier will demand more than can be made available, so this decade has the ability to put in a maximum of 11 000 bits.

Before the third decade is tried the reference bias is removed. This is approximately 8 bits, so the major choices in the first two decades will have settled to their nominal values. The third decade also can count up to 11, and it is arranged that a "Ten" occurring in the second or third decades is carried to the display. The remaining decades are limited to a count of 9 and can not generate carry information.

Table 3.2 Logic Decisions

ACTUAL INPUT	4	0	0	0	3
DECISIONS TAKEN	4	8	8	8	8
	2	4	4	4	4
	2	2	2	2	2
	1	1	1	1	1
SUB-TOTAL	3	9	10	0	3
DISPLAY	4	0	0	0	0

Some examples are shown which illustrate the logic. Assume an input of 4.0003 volts [shown in Table 3.2]. The first decade tries the 4 and rejects it because this choice has been biased to approximately 4.0008. The 2 is accepted, the second 2 rejected, and the 1 accepted. The total reference so far selected is thus [with bias] 3.0008. The next decade finds that it is .9995 short. It chooses 8. The 4 is then inhibited. It tries 2 and rejects, but accepts 1. Total reference is now 3.9008, but at this point the bias is removed. Hence the reference falls to 3.9000 and the next decade [Hundreds] finds that it is short of .1003

This decade then selects 8, inhibiting 4, and selects 2. It tries 1 and rejects. There is then a total of 10 in this decade. The total reference so far selected is now 4.0000. The fourth decade [Tens] finds that all reference bits are too large and rejects them all. Total reference remains at 4.0000 and the fifth decade [Units] finds it is short of .0003. This decade rejects 8 and 4 but accepts 2 and 1 making a total of 3. The decoding is arranged to in effect carry the 10, so that the displayed reading is 4.0003.

Table 3.3 Logic Decisions

ACTUAL INPUT	2	9	1	0	5
DECISIONS TAKEN	~~4~~ 2 ~~2~~ ~~1~~	8 ~~4~~ ~~2~~ ~~1~~	8 ~~4~~ 2 1	~~8~~ ~~4~~ ~~2~~ ~~1~~	~~8~~ 4 ~~2~~ 1
SUB-TOTAL	2	8	11	0	5
DISPLAY	2	9	1	0	5

In the next example [Table 3.3] the input is 2.9105. The first decade selects 2, but in the second decade it is assumed that, due to overshoot, 8 is selected rather than 9. The third decade can then give 11 and the correct reading is achieved.

Table 3.4 Logic Decisions

ACTUAL INPUT	1	0	.	1	8	4	7
DECISIONS TAKEN		4 2 2 1		8 ~~4~~ 2 1	8 ~~4~~ 2 ~~1~~	~~8~~ 4 ~~2~~ ~~1~~	~~8~~ 4 2 1
SUB-TOTAL		9		11	8	4	7
DISPLAY	1	0	.	1	8	4	7

Table 3.4 shows another possibility in which a carry occurs from the second decade.

From the codes used it would appear that the maximum display should be 102199. This was considered to be rather inelegant, so it has been deliberately limited to 101999 as shown in Table 3.5.

Table 3.5 Logic Decisions

ACTUAL INPUT	1	2	0	0	0	0
DECISIONS TAKEN		4 2 2 1	8 ~~4~~ 2 1	8 ~~4~~ 2 1	8 ~~4~~ 2 1	8 ~~4~~ 2 1
SUB-TOTAL		9	11	9	9	9
DISPLAY	1	0	1	9	9	9

SECTION 4
CIRCUIT DESCRIPTION

Board Identification

In the following description the boards are identified by their position in the LM1867. Where necessary, the board on which a specific component is mounted is given before the component reference, viz:-
1 - R9 designates resistor R9 on board No. 1
1 - B10 designates terminal B10 on board No. 1
1 - VT10 designates transistor VT10 on board No. 1

Input Attenuator

The input attenuator consists of a resistive voltage-dividing chain, R9, R36, RV1, R37, RV2 R39, and R38, connected between the signal input and common rail. On the basic 10 volts range, the signal input is applied direct to the filter input via resistor R89. On the 100 and 1 000 volts ranges, the appropriate tap on the divider chain is selected by switch-bank SF4R to divide-down the input by factors of 10 and 100 respectively. Thus the signal voltage applied to the balance amplifier for a full-scale input on the 100 or 1 000 volts ranges will be 10 volts. On the 1 volt range, the signal input is again routed directly to the filter input via resistor R89. Correct scaling [1 volt f.s.d.] is achieved by dividing-down the reference voltage in the ratio of 10:1. The attenuated reference voltage is developed via switch-bank SF5F in position 1. The fifth [CAL.] position of the range selector SF, when used in conjunction with the centre-biased key-switch SD, enables the instrument zero to be set, and also permits the positive and negative reference sources to be calibrated against the internal standard cell BY1.

Input Filter

An input filter is provided to permit the measurement of signals having a high noise content. The FILTER selector SG switches the RC elements to provide choice of 60, 80 or 90dB attenuation at 50Hz, or 90dB at 100Hz. A through connection is provided in the first [OUT] position of the selector. The filter is a twin-T section, tuned to 50 or 100Hz as appropriate, followed by an RC low-pass section.

Input and Balance Amplifier (Board Nos 15 and 16)

The input amplifier comprises two hard valve stages mounted on board No. 15 and three transistor emitter-coupled differential amplifiers on board No. 16. The input differential amplifier employs two cathode-coupled electrometer pentodes 15 - V1 and 15 - V2. HT is derived from the +50 volts stabilised supply and the heaters are energised from the -10 volts supply on board No. 13. 15 - MR3 protects V1 from possible damage due to excessive input voltages by limiting the cathode positive excursion to approximately +15 volts as defined by the potential divider 15 - R5, 15 - R6. The input to the grid of V1 is switched between the signal input [drift-correct period] and the reference input [reference period] by chopper relay RLA/1. For the duration of the drift-correct period, the grid of V2 is connected, via a second chopper relay RLB/1, to the output of the amplifier [pin 7, board No. 16] to form an overall feedback loop. The voltage then fed-back to the grid of V2 will be equal in amplitude to the sum of the signal input and drift voltages, and the drift-correct capacitor [C14 and/or C16] will be charged to this potential. During the reference period, the grid of V2 is disconnected from the output of the amplifier by relay RLB/1, and the input to that grid is now the voltage stored on capacitor C14 or C16 which, in addition to being quantitively equal to the sum of the input and drift signals, will also be of the same polarity as the input signal. As a result of the differential action of V1 and V2, the reference input applied to V1 grid to balance-out the signal voltage stored in C14 or C16 must be of the same polarity as the input signal. A balanced output is taken from the anodes of V1 and V2 and applied via emitter followers VT9 and VT10 to the final stages of the balance amplifier. These consist of three emitter-coupled differential amplifiers [VT1-VT6] connected in cascade, the last of which drives two emitter-follower output stages [VT7, VT8]. Resistors R7 and R9, wired in the emitter circuits of VT1 and VT2, provide current feedback to minimise the effect of transistor parameter spreads. For the same reason, negative feedback is taken from the collectors of VT5 and VT6, and applied to the bases of VT4 and VT3 via resistors R18 and R17. Diodes MR1 and MR2 are connected between the emitters and bases of VT5 and VT6 to limit the reverse bias applied to these transistors. Balanced drive from the collectors of VT5 and VT6 is applied to emitter followers VT7 and VT8 to provide opposite polarity outputs at pins 2 and 1 respectively. The overall gain of the input amplifier from the grid of V1 to the outputs at the emitters of VT7 and VT8 is of the order of 1.5×10^6 and is accurately set to 1×10^6 by 16 - RV1.

Reference Supply Sources and Switching (Board No.1)

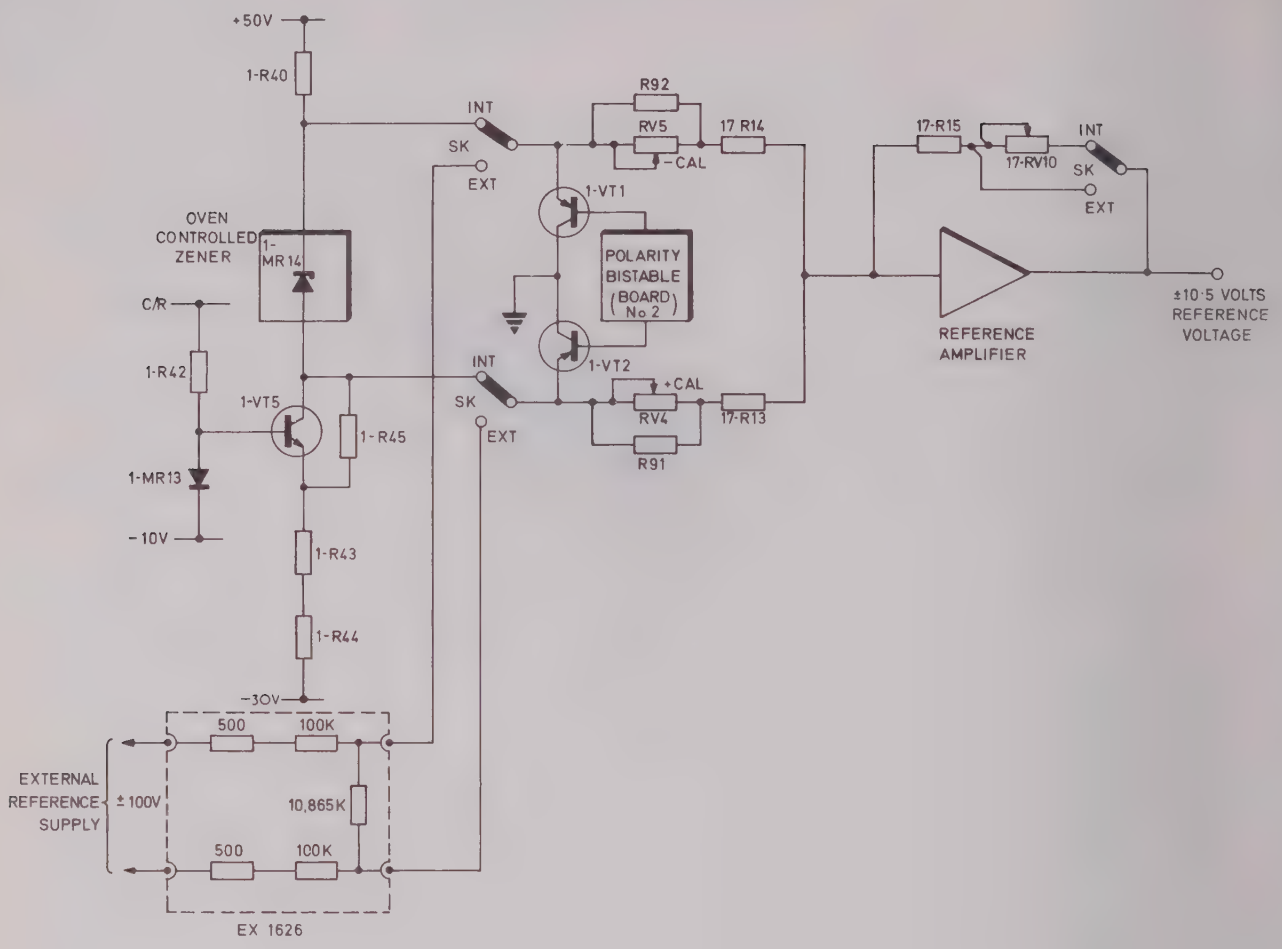


Fig. 4.1 Reference Supplies and Switching

The positive and negative voltage reference sources are both derived from an ovened zener diode MR14. The oven is constructed of polycrystaline semi-conductor material, and offers the advantages of a short temperature stabilising period [3 mins.] and low power drain. The high order of inherent thermal stability provided by the oven is further enhanced by energising from a stabilised d.c. supply. The zener current through MR14 is drawn from a stabilised voltage source via the constant current device VT5. The positive and negative reference supplies are obtained by respectively earthing the anode or the cathode of the zener diode via one or other of two transistor switches driven from the outputs developed across the collector loads, R5, R9, of the polarity bistable VT3/VT4 [board No. 2]. In the presence of a positive input signal to the instrument, the control signals developed across R9 and R5 will stand at +12 and -20 volts respectively. These signals are applied to the bases of the p.n.p. switching transistors to cut off VT2 and to turn on VT1, this latter operation earthing the cathode of the reference zener via the INT. positions of switch bank SK. Thus a negative reference potential of -6.2 volts with respect to earth is developed at the anode of 2 - MR14, and applied to the reference amplifier input via switchbank SK [INT], RV4, and 17 - R13.

Conversely, for a negative signal input, the output from the polarity bistable will be reversed, and transistor VT2 will conduct to earth the anode of MR14, thus applying a positive reference potential to the reference amplifier via SK [INT], RV5, and 17 - R14. Variable resistors, RV4 [+ve CAL] and RV5 [-ve CAL] are panel mounted preset controls, enabling the internally derived reference voltages to be standardised against the internal standard cell. Resistors 17 - R13 and 17 - R14 form the reference amplifier input resistance, which in conjunction with the feedback resistor 17 - R15, determine the gain of the amplifier. Preset variable resistor 17 - RV10, connected in series with 17 - R15 on internal reference working, provides fine control of the amplifier gain to apply compensation for zener voltage tolerance.

External Reference Operation

For operation with an external reference voltage, the positive and negative external reference sources are applied, via an External Reference Unit, to the reference amplifier input circuit. Each Reference Unit contains a symmetrical voltage dividing network, the values of the arms being so selected with regard to the level of the external reference voltage, as to develop a potential of the order of ± 6.5 volts at the appropriate reference amplifier input resistance, when the corresponding point of the other input circuit is earthed. As in the case of internal reference working the switching operation is performed by transistors 1 - VT1 and 1 - VT2 at the command of the polarity bistable.

Reference Amplifier (Board No.14)

The reference amplifier is fed with the output from the appropriate [positive or negative] reference source, and produces at its output a stabilised ±10.5 volts supply for application to the reference resistors. The input is applied at terminal A4 and taken to the first grid of the double-triode V1, which is connected as a cathode-coupled differential amplifier. The input signal is chopped at 50Hz by paralleled transistors VT1 and VT2, which are driven by a mains excited squaring circuit, whose output is applied to terminal A10. A balanced output is taken from the anodes of V1 via emitter followers VT11 and VT12 to the bases of VT3 and VT4 which are connected as an emitter-coupled differential amplifier.

Phase-shifting networks C2, R8, and C4, R15 maintain stability. Transistors VT6 and VT7 also function as a differential amplifier, with a stabilising phase-shift provided by capacitors C5 and C6. Diodes MR4 and MR3 ensure that the reverse bias applied between the bases and emitters of these transistors cannot exceed the breakdown voltage.

The reference output is taken from the emitter of VT10, which with VT9 forms a compound emitter-follower driven from the collector of VT6. Overall negative feedback is taken from the amplifier output terminal A8 to the input via 17 - R15. A feedback voltage is also taken from the collector of VT7 and applied to the grid of V1B via R10. This latter feedback loop is chopped at mains frequency by transistor VT5, which is driven on its base by the 'B' phase of the squaring circuit applied at terminal A9. This 'B' phase is 180 degrees out of phase with the 'A' phase driving the input chopper transistors VT1 and VT2. Thus when VT1 and VT2 are conducting, no input signal is applied to V1A. Any signal now appearing at the collector of VT7 will be due to drift in the amplifier. Since VT5 will now be cut-off by the 'B' phase, this drift signal will be coupled via R18, R33 and R10 to the grid of V1B, where it will remain stored in capacitor C3. When the chopper drive changes phase, transistors VT1 and VT2 will cut-off to permit the input signal to be applied to V1A and, at the same time, VT5 will conduct to short the feedback signal to a point of low impedance.

Since, because of stray capacitance, the input impedance to the instrument is affected by the voltage present on RLA pin 6, it is necessary that the d.c. level at the output [terminal A8] of the reference amplifier be maintained at the same potential [+ or -10.5 volts] during both the drift-correct and reference periods. In this manner, a high and constant impedance can be achieved. To this end, transistor VT8 is driven on its base by the 'A' phase of the squaring amplifier, which phase also drives the input chopper transistors VT1 and VT2. Since this phase is negative during the drift-correct period, transistor VT8 will for the duration of that period conduct to apply the ±10.5 volts potential present at terminal A11 to the base of VT9, which in turn lifts the output at VT10 emitter to the same potential.

The ±10.5 volts potential on terminal A11 is derived from two emitter followers VT12/VT13 mounted on board No. 1, the appropriate polarity being selected by reference to the polarity bistable. Assuming a positive signal input to the instrument, the outputs from the polarity bistable at terminals 1 - B11 and 1 - B5 will be -20 and +12 volts respectively. These potentials are applied to the bases of the emitter switch transistors 1 - VT6 and 1 - VT7, so that VT6 conducts and applies the +10.5 volts potential present at the emitter of of 1 - VT13 to the collector of 14 - VT8 via terminals 1 - B12 and 14 - A11. Potentiometer 1 - RV1 is a preset adjustment enabling 1 - VT13 output to be set to precisely +10.5 volts, whilst 1 - RV2 performs the same function on the negative output from 1 - VT12.

Ring Counter

The ring counter consists of twenty two, cascaded, R.C. coupled transistors, the emitters of which are all returned to a common emitter rail. This rail is negatively pulsed at 250 microseconds intervals by the 4kHz clock oscillator to step the ring successively from stage to stage. The order of stepping, numerical significance, transistor component references, and board numbers are listed in Table 4.1.

Table 4.1 Ring Counter Stepping Order

Order	Significance	Transistor	Board No.
1	Polarity	VT2	2
2	Delay	VT5	2
3	40 000	VT3	4
4	20 000A	VT6	4
5	20 000B	VT9	4
6	10 000	VT12	4
7	8 000	VT3	6
8	4 000	VT6	6
9	2 000	VT9	6
10	1 000	VT12	6
11	800	VT3	8
12	400	VT6	8
13	200	VT9	8
14	100	VT12	8
15	80	VT3	10
16	40	VT6	10
17	20	VT9	10
18	10	VT12	10
19	8	VT3	12
20	4	VT6	12
21	2	VT9	12
22	1	VT12	12

When the ring start bistable transistor 19 - VT1 is cut off by the first negative emitter rail pulse, a negative signal is developed at its collector and applied to the base of the polarity ring stage transistor 2 - VT2. This transistor now passes current for a period of 250 microseconds until cut-off by the succeeding negative emitter rail pulse. The output from the collector of 2 - VT2 is differentiated by C3 and R10 to produce a positive and negative pulse respectively at the commencement and termination of the conduction period. These pulses are applied via capacitor C1 and R9 to the polarity bistable 2 - VT3, 2 - VT4, which is turned-over by the positive leading pulse, and will be reset by the negative pulse, 250 microseconds later, unless this reset pulse is absorbed by the gate line. [Refer to paragraph "Polarity Bistable and Decision"]. The negative voltage developed at the collector of VT2 when it is cut-off at the end of its 250 microseconds conduction period, is applied to the base of the delay ring-counter stage VT5 via the differentiating network C3, R10. Transistor VT5 now conducts for a period of 250 microseconds until cut-off by the next emitter-rail pulse. In this manner the ring counter is stepped from stage to stage in the order given in Table 4.1, until finally the system once again rests in the stable state with 19 - VT1 conducting.

Start Circuitry

General

Part of this circuitry, namely the sample bistable, ring start bistable, and 4kHz oscillator is carried on board No. 19. The start gate and squaring amplifier synchronising the gate to the mains frequency are mounted on board No. 1. The start gate is operated by the coincident application of a signal input from one of three sources, [according to the mode of operation to which the instrument is switched by the mode selector SH,] and a mains synchronised pulse.

Table 4.2 Start Gate Operating Modes

Mode	Signal Input
Max.	Balance amplifier output
Min.	Balance amplifier output
Resolution 1, 2, 5	Balance amplifier output
Manual Sample	Sample bistable output
Variable Sample	Capacitor charging circuit

Manual Sampling Operation

A single-shot conversion is initiated by depressing the MANUAL SAMPLE push-button SC to discharge capacitor 19 - C4 to common rail via R23 and R40. Alternatively this function can be performed by the closure of remote contacts connected across pins 1 and 27 of socket SKA, or by the application of a 4 volts positive pulse across pins 27 and 28 [common rail] of socket SKA. The discharge current develops a positive pulse at the junction of R19 and C4, to turn-over the sample bistable by cutting-off VT8 via MR3. The collector of VT9 then rises from approximately common rail to +20 volts which potential is applied to the start gate via MR7 and terminal 1 - A6.

The start gate [board No. 1] consists of a squaring amplifier VT10, driven on its base by a suitably phased mains synchronised a.c. input. The square-wave output appearing at its collector is differentiated by C1 and R25 to produce positive pulses of 10 volts amplitude at the junction of R28 and MR11, diode MR12 being forward-biased by the +20 volts applied via switchbank SH2F. The start pulse generator transistor VT11 is controlled by an "and" gate consisting of diodes MR10 and MR11, both of which must be opened to permit VT11 to be triggered to deliver the ring start pulse. In the quiescent condition, transistor VT11 is held-off by the positive potential applied to its base via the voltage divider R29, MR11, R28. The cathode of MR10 is held at a potential of +12 volts via the voltage divider R27, R26, R24, and

will be forward-biased, as will MR11 by virtue of its cathode potential as determined by the divider R25 and R28. On the incidence of the +20 volts pulse from the sample bistable to terminal 1 - A6, the cathode of MR10 will be driven positive to reverse-bias the diode and thus open one gate to transistor VT11, which is now held-off by the +15 volts potential applied via R29 and R28. The next positive pulse delivered by the squaring circuit will reverse-bias diode MR11 so that a current pulse flows through R29 into the base of VT11, which conducts to generate the negative ring start pulse at its collector. The pulse is differentiated and coupled to the ring control circuits on board No. 19 via terminal 1 - A2.

Ring Control Circuits (Board No.19)

These circuits comprise the 4kHz clock oscillator, the ring reset stage, and the sample bistable, the function of which has been described in paragraph 'Manual Sampling Operation'. The negative start pulse from 1 - VT11 is applied via diode MR2 to the base of transistor VT3, which then conducts. The +20 volts on VT3 collector is passed via emitter-follower VT4 to the base of VT6.

Transistors VT6 and VT7 form an emitter-coupled relaxation oscillator operating at a frequency of 4kHz with a mark/space ratio of 8 : 1. When VT3 is switched off VT6 base is clamped to common rail by VT4 and the oscillator is held off. When VT3 is conducting, VT6 base rises to +20 volts and oscillations commence. The positive-going edges of the oscillator waveform are used to trigger the decision logic circuits via emitter-follower VT11. The negative-going edges pulse the ring step bar via the emitter-follower VT10.

The negative start pulse from 1 - VT11 is applied via diode MR2 to the base of transistor VT3 to turn over the ring start bistable. VT3 conducts, cutting off VT1. The negative-going edge developed on VT1 collector is passed via terminal A4 to the base of transistor 2 - VT2 to set the ring to its first [polarity] position. The 4kHz pulses on the ring step bar now step the ring through its subsequent positions until the last stage is reached when transistor 12 - VT12 is cut off. The negative pulse at VT12 collector is applied via terminal 19 - A12 to the base of transistor VT1 where it resets the ring start bistable, cutting off VT3. VT4 emitter is now at common rail and the 4kHz oscillations cease. The ring reset pulse also produces a positive-going edge at VT1 collector which is passed via C7 and MR4 to the base of VT9, returning the sample bistable to the 'ready' condition. The sequence is now complete and the ring counter rests in the stable state awaiting a further start command.

Continuous Sampling with 1, 2 or 5 Bit Resolution

In these modes of operation the positive signal to the start gate is taken from the output of the balance amplifier. This method of starting provides improved discrimination against noise voltages when operating on the 1 volt range with 1-bit resolution by ensuring that the ring will not be tripped on every cycle of the mains frequency input, if the input voltage applied to the instrument remains unchanged. The positive side of the amplifier output is applied to the gating circuit via diode MR16 or MR17, and switchbanks SC2 and SH1F. A signal amplitude of 8 volts is required to 'open' gate diode 1 - MR10. Such a signal will be produced by a 7μV input to the balance amplifier. In the balance condition, the output level from the balance amplifier will be approximately zero volts and no ring start pulses will be passed to the ring start bistable. The ring thus remains in the rest position. If the input voltage changes by 7μV or more, the 8 volts output developed by the balance amplifier will permit the ring to be triggered by the next mains synchronising pulse delivered by 1 - VT10. The same method of ring starting is used on RESOLUTION 2 and 5. On all three modes of operation, the instrument reading can be 'frozen' by depression of the MANUAL SAMPLE push-button SC. This causes contact SC2 to open to disconnect the start gate from the balance amplifier output, and to 'close' gate diode 1 - MR10 by the application of forward bias.

Maximum or Minimum Reading Operation

In these modes of operation, the instrument will read and hold displayed the greatest positive or greatest negative excursion of a slowly varying signal. As in the case of RESOLUTION 1, 2 or 5 operation, the positive signal to the start gate is derived from the output of the balance amplifier. For maximum working, the signal is taken from the in-phase output [terminal A1] of the balance amplifier, whilst for minimum working it is taken from the anti-phase output [terminal A2]. For a constant [unchanging] input, the output level from the balance amplifier will stand at approximately zero volts, and the ring will be 'locked-out' so that the displayed reading remains unchanged. If now the input voltage commences to rise, [moves positively] the balance amplifier will develop a positive output at terminal A1, which is applied, via diode MR19 and switchbank SHIF in the MAXimum position to the start gate. The gate will open when the amplifier output exceeds +8 volts, and the ring will be triggered by the mains frequency synchronising pulses. Should the input voltage stop rising the balance amplifier output will fall below +8 volts and the ring will 'lock-out'. The instrument will now hold displayed that reading initiated by the last synchronising pulse delivered before the 'lock-out'. Any subsequent decrease [negative movement] of the input voltage will cause the balance

amplifier to develop a negative output at terminal A1 which will be blocked from the start gate at the diode MR19. The minimum [negative excursion] reading facility is provided by the same means, with the exception that the negative movement of signal input voltage is translated to a positive movement by taking the trigger signal from the anti-phase output of the balance amplifier. On either mode of operation, the instrument can be reset by operation of push-button SC to turn-over the sample bistable 19 - VT8, 19 - VT9 and thus trigger the ring for a reading.

Variable Sample Operation

In this operational mode, the ring triggering signal is derived from the voltage stored in a timing capacitor. The frequency of triggering, and therefore sampling, is controlled by varying the rate of charge of the capacitor by means of a variable resistor RV15. Range selection is effected by switchbank SH3F, which selects capacitor C12 or C13 for the '0-5' or '0-150' ranges respectively. Assuming that transistor 19 - VT13 is cut-off, the selected timing capacitance will draw charging current via terminal 19 - B7, R37, R36, terminal 19 - A9, and the timing resistor RV15. When the voltage on the timing capacitor rises to approximately +15 volts, diode 1 - MR12 will become forward-biased, and since the diode 1 - MR10 is held open by the positive potential applied to the junction of R24 and R26 via switchbank SH1F, the start gate VT11 will be triggered by the first mains synchronising pulse delivered after the 'opening' of 1 - MR12. The ring will now run through one cycle, and the instrument will display a reading. At the commencement of the ring cycle, the ring start bistable transistor 19 - VT1 will be cut-off by the negative start pulse. The negative signal developed at its collector is applied to the base of transistor 19 - VT12 which conducts to apply a positive signal to the base of 19 - VT13. Transistor VT13 now passes current to discharge the timing capacitor via diode MR11 and the current limiting resistor 19 - R36. At the end of the digitisation period when the ring is returned to the stable state with 19 - VT1 conducting, the positive signal developed at its collector will cut-off VT12 and hence VT13 to open the discharge path of the timing capacitor, which thereupon commences to recharge.

Reset Circuit (Board No.19)

The function of this circuit, which comprises a two-stage transistor amplifier VT2, VT5, is to return all quantity bistables to the 'off' condition at the commencement of a conversion. When the ring counter is stepped from the stable state to the polarity stage, transistor 2 - VT2 passes current and develops a positive voltage at its collector. This signal is applied to the base of 19 - VT2 via terminals 2 - A3, 19 - A3, and resistor R5, to produce a positive output at the collector of VT5. This signal is applied to the bistable reset line via terminal B4 to clear-down all quantity bistables in readiness for the next conversion. When the ring is stepped from the polarity stage to the delay stage [2 - VT5], transistor 19 - VT2 is cut-off to remove the clear-down signal from the reset line.

Print Command Signal (Board No.19)

During the ring cycle transistor VT4 emitter stands at a potential of the order of +20 volts. On the conclusion of a conversion, VT4 emitter moves negatively from +20 volts to common rail potential. This step function is differentiated by C3 and R16, and the resultant negative pulse passed via MR6 to pin 3 of socket SKA as a print command signal.

Polarity Bistable and Decision Logic Circuits

General

This circuitry is mounted on board No. 2. The ring counter polarity and delay stages, and the transistors providing the 'A' and 'B' phase mains frequency square-wave drive to the reference amplifier chopper transistors are also carried on this board.

Polarity Bistable and Decision

The polarity bistable consists of transistors VT3 and VT4, and normally rests with VT4 conducting, this being the condition for a positive polarity decision. When the bistable is turned-over to the negative condition by the positive pulse from the polarity ring counter stage VT2, VT4 is cut off and VT3 on. The bistable rests in this condition for a period of 250 microseconds and will then be returned to the positive condition by the negative pulse produced on VT2 collector as the ring is stepped to the second position, unless this pulse is absorbed by the gate line. The decision as to whether the reset pulse be gated or not is taken by the decision logic circuits acting on signal polarity information provided by the balance amplifier. Assuming a negative input voltage to the balance amplifier, a negative charge will be stored on 15 - V2 grid capacitor which in the absence of the reference input to 15 - V1 will produce a positive output at the emitter of 16 - VT7. This voltage is applied to the base of transistor 2 - VT7 producing a positive potential at the emitter to switch VT8 on and VT9 off. VT9 collector now falls to approximately -15 volts. VT8, MR11 and MR4 prevent the collectors of VT10 and VT11 from going positive with respect to common rail.

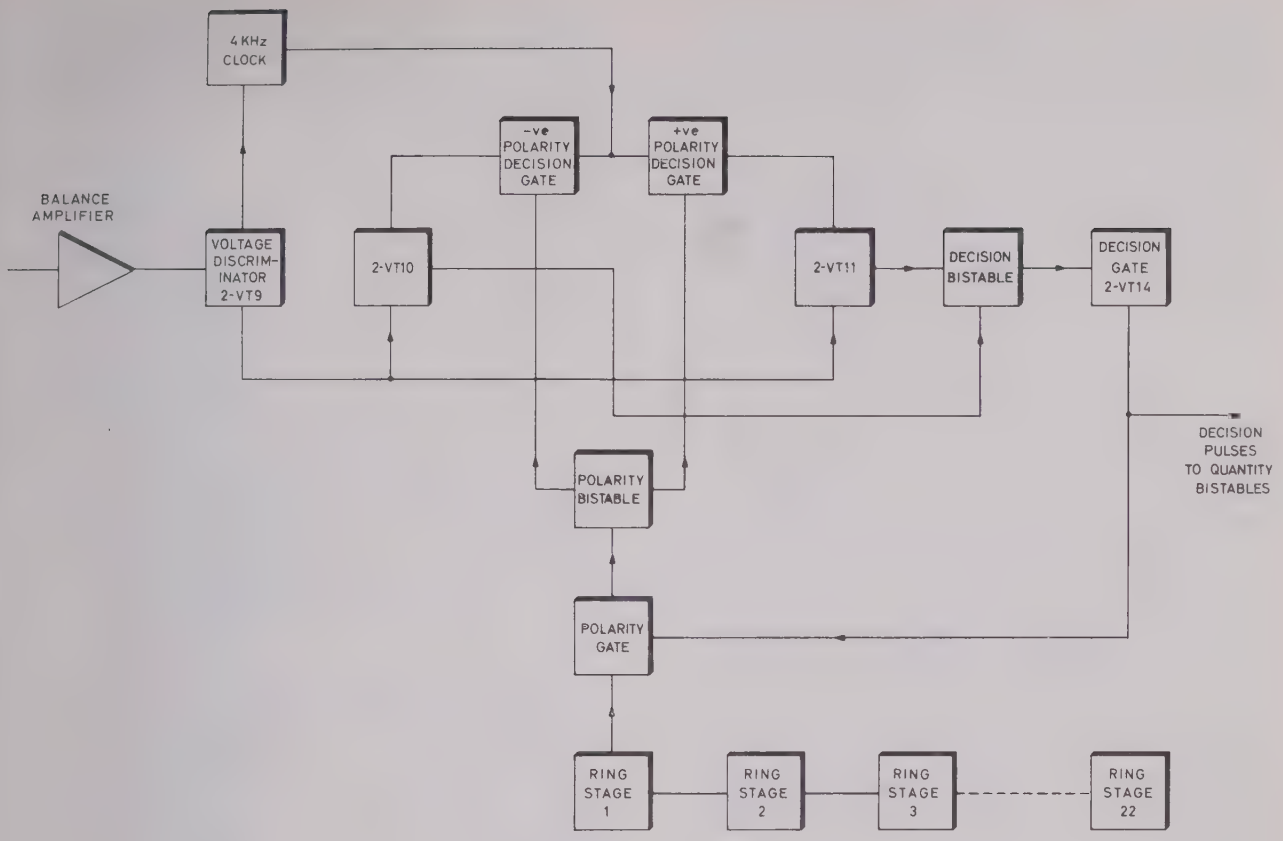


Fig. 4.2 Decision Logic

As the polarity bistable has previously been set to the negative condition, VT3 collector will be at +12 volts and VT4 collector approximately -20 volts. These voltages are applied via emitter followers VT1 and VT6 to the cathodes of MR6 and MR10 respectively. MR6 is now cut off. VT10 conducts due to the potential applied to the base by R24, MR5 and R23. VT10 base and hence MR5 anode are held at approximately common rail potential with MR5 conducting.

MR10 conducts via R29 to hold its anode at -20 volts. VT11 conducts due to the negative potential applied to the base via R30. VT11 base, and hence MR9 anode, is held at common rail potential with MR9 cut off.

A positive decision pulse from the 4kHz clock is applied to the cathodes of MR5 and MR9 via terminal A1. MR9 is reverse biased but MR5 conducts allowing the pulse to cut off VT10 and produce a negative pulse at the collector. This pulse is applied to VT13 base to set the decision bistable such that VT13 is on and VT12 off. VT12 collector is thus at a negative potential which is applied via R39 to VT14 base. VT14 switches on and the collector rises to +12 volts holding MR2 cathode at this potential.

The negative reset pulse generated at VT2 collector is now applied to C1 but MR2 conducts to clamp the junction of R7 and R9 to +12 volts. The polarity bistable therefore remains in the negative condition. All subsequent decision pulses are routed via VT10 to the gate transistor VT14.

The +12 volts present at terminal B6 and the -20 volts at B5 are routed to the emitter switches 1 - VT1 and 1 - VT2 respectively. VT1 is cut off but VT2 switches on to connect the negative terminal of 1 - MR14 to common rail and thus apply a +6 volt input from terminal 1 - B2 via SK and RV5 to the input of the reference amplifier. Following a polarity inversion within the amplifier, a -10.5 volt d.c. potential is applied to the reference resistors. Once taken, the polarity decision is irrevocable, and the conditions imposed on the decision logic transistors 2 - VT10 and 2 - VT11 hold for the duration of a ring cycle.

If a positive input voltage is applied to the balance amplifier, the voltage at 2 - VT7 base will be negative, producing a negative potential at the emitter to switch VT8 off and VT9 on. VT9 collector rises to +12 volts. As before, the polarity bistable will have

been set to the negative condition and the same potentials will be present on MR9 and MR10 anodes. MR9 will be cut off and MR5 conducting.

Because of the +12 volts present at VT9 collector, transistors VT10 and VT11 are reverse biased. Under these conditions the reverse gain characteristic of the transistors is used, the collector potential following the base. The positive decision pulse, when applied to VT10 base, will thus produce a positive pulse at VT10 collector, switching off VT13 and causing VT12 collector to rise to common rail potential by bistable action. VT14 base is now held positive and the transistor cuts off. MR2 anode is returned to +12 volts via R40 and the reset pulse on VT2 collector is allowed to pass via R9 to the base of VT4. The polarity bistable will therefore be reset to the condition appropriate to a positive input, reversing the potentials on the bases of emitter switches 1 - VT1 and 1 - VT2 so that VT1 is on and VT2 is off. A negative potential is now applied to the input of the reference amplifier and a +10.5 volt d.c. potential connected to the reference resistors.

As the polarity bistable has been reset, the potentials on the anodes of 2 - MR6 and 2 - MR10 are reversed resulting in MR5 being cut off with MR10 conducting. Subsequent decision pulses from the 4kHz clock will pass via VT11 and the decision bistable to the decision gate transistor VT14.

Polarity Indication

When transistor VT4 is switched off [i.e. a negative polarity has been selected] transistor 18 - VT1 is held off by the negative potential applied to its base via terminals 2 - B5 and 18 - p1. The positive sign neon indicator ILP8 is thus extinguished while ILP7 strikes to display a negative sign. The potential at the junction of R120 and ILP7 is now held at approximately +75 volts. Should a positive polarity be selected, 18 - VT1 switches on and ILP8 strikes since its cathode is now returned to common rail. ILP8 anode falls to approximately +25 volts causing ILP7 to extinguish as it does so.

Quantity Decision (Board No.2)

The polarity of the output from the balance amplifier to the emitter follower VT7 is employed to operate the decision gate VT14. Increments of reference voltage equalling or falling-short of the signal input will drive the balance amplifier output in one direction, whilst any reference increment exceeding the signal input in magnitude will drive the amplifier to its limit in the opposite direction. Assuming a positive voltage input to the voltmeter, the positive decision pulses will be routed to transistor VT11 after the polarity decision has been taken. Furthermore, if the initial signal from the amplifier output to VT7 is of negative polarity, VT9 will conduct to bring its collector to a potential of +12 volts. A positive decision pulse now applied to VT11 will produce a positive pulse at its collector, and thus cut-on the decision gate transistor VT14 so that the quantity bistable reset pulse is absorbed, and the bistable remains in the 'on' condition in which the reference increment is accepted. If now a reference increment is applied which causes the total reference voltage to exceed the signal voltage, the polarity of the balance amplifier output will swing from negative to positive. The signal cuts-off VT9 so that its collector potential falls to approximately -15 volts. When VT11 is cut-off by a positive decision pulse, a negative pulse is developed at its collector to drive the decision gate transistor VT14 into cut-off. In this circumstance, the negative reset pulse is not absorbed, but is applied to the quantity bistable to return it to the 'off' condition in which the reference increment is rejected.

Squaring Amplifier (Board No.2)

The function of this circuit is to provide two anti-phase, mains frequency, square-wave signals for driving the chopper transistors in the reference amplifier. Mains frequency drive is taken from pin 33 of the mains transformer and applied to the base of transistor VT15, which provides the 'B' phase. The 'A' phase is generated by transistor VT16 which is driven on its base by VT15 collector output to effect the polarity reversal. The 'A' and 'B' phases are routed to the reference amplifier via terminals B10 and B9 respectively.

Quantity Bistables and Ring Counter Stages

General

These circuits for the 10 000, 1 000, 100, 10 and 1 decades are mounted on board Nos 4, 6, 8, 10 and 12, respectively.

1 and 10 Decade Bistables and Ring Counter Stages (Board Nos 10 and 12)

The following description refers specifically to the decade circuits mounted on board No. 12, but is equally applicable to the 10 decade stage on board No. 10. The 8 bistable consists of transistors VT2 and VT4. In the quiescent [pre-conversion] condition, transistor VT4 is on and VT2 is off. When the 8 ring counter stage VT3 is cut on by the negative pulse from the previous stage, a positive pulse is developed at VT3 collector and capacitively coupled via C1 to the base of VT4. The bistable is thereby turned-over to the 'on' [reference

accepted] condition. At the end of its 250 microseconds conduction period, VT3 is cut-off by the negative emitter rail pulse, and develops a negative reset pulse at its collector. If the gate-line is, at the command of the decision logic circuits, shorted to the +12 volts rail via the decision gate transistor 2 - VT14, diode MR4 will be forward-biased and the negative reset pulse will be absorbed, leaving the bistable in the 'on' condition. If, however, the decision gate transistor 2 - VT14 is cut-off, the reset pulse will not be absorbed but will be applied to the base of VT4 to cut-off this transistor and thus return the bistable to the 'off' [reference rejected] condition. The general reset line, which moves to approximately +20 volts when the ring counter is stepped to the polarity stage, - reference paragraph 'Reset Circuit [board No. 19]' - is applied to the base of VT2 via the diode MR3 to return the bistable to the 'off' condition in readiness for the impending conversion. The bistable outputs to the emitter switches are taken from the collectors of VT2 and VT4 via terminals B9 and B10.

A veto circuit is incorporated to ensure that no decade exceeds a count of '9' by inhibiting the operation of the '4' and '2' bistables after the acceptance of the '8' increment. Referring to the units decade, [board No. 12], when the 8 reference has been accepted, the bistable VT2/VT4 will be left in the 'on' condition, i.e. VT4 will be cut-off, and its collector will stand at a potential of approximately -20 volts. Diode MR1 anode is returned to -30 volts via R3. MR1 will conduct clamping VT1 base to the -20 volts on VT4 collector. In this condition VT1 will pass current and develop a potential of the order of -5 volts at the junction of emitter resistor R1 and diode MR17. This signal is applied, via diodes MR8 and MR13, to transistors VT7 and VT10 of the 4 and 2 unit bistables, to bias these circuits in the 'off' [reference rejected] condition for the duration of that ring-cycle. If the 8 units of reference is rejected, the associated bistable will be returned to the 'off' condition with VT4 conducting. The resultant +12 volts signal developed at its collector is applied to the base of VT1, via diode MR1. Transistor VT1 is thereby cut-off. The junction of R1 and MR17 rises to +50 volts and the negative lock-out potential is removed from the bases of VT7 and VT10. If the 8 units are rejected, the negative lock-out voltage will be applied to the 4 and 2 unit stages for that period, namely 250 microseconds, during which the 8 bistable rests in the 'on' condition with VT4 cut-off. At the end of this period the 8 bistable will reset to the 'off' condition and the inhibiting voltage will be removed from the 4 and 2 stages. Coincident with the removal of this voltage, the 4 units bistable will receive a positive firing pulse to turn it over to the 'on' [reference accepted] state. In these circumstances it is possible that the 4 bistable would 'miss-out'. To prevent this, the inhibiting voltage is removed at the moment of decision which occurs 30 microseconds before the 8 bistable is returned to the 'off' condition. For this purpose an output is taken from the collector of transistor VT12 of the decision bistable mounted on board No. 2. When the decision is taken to reject the 8 units increment, the collector of VT12 will move positively towards common rail potential. This signal is applied via terminals A9 and diode MR2 to the base of 12 - VT1 to cut-off that transistor and thereby remove the inhibiting voltage from the 4 and 2 unit bistables. Thus when the 4 units bistable is triggered 30 microseconds later the inhibiting signal will already have been removed and the operation of the bistable is assured.

Emitter Switches

General

The reference resistors are switched in or out of circuit by means of transistor emitter switches.

The use of transistor switching obviates contact resistance problems associated with relay switching, and has the additional advantage of effecting faster switching speeds and making the instrument silent in operation. The switching operation is performed by the application of positive and negative drive potentials to the bases of transistors from the quantity and polarity bistables. The positions of the boards carrying emitter switches are listed in Table 4.3 which also gives the transistor component reference and the switching function performed.

Table 4.3 Emitter Switches and Functions

Item	Board No.	Transistor	Function	
[1]	1	VT1/VT2	Reference supply switching	
[2]	3	VT15/VT16	40 000	Increments
		VT17/VT18	20 000A	
		VT19/VT20	20 000B	
		VT21/VT22	10 000	
[3]	5	VT15/VT16	8 000	Increments
		VT17/VT18	4 000	
		VT19/VT20	2 000	
		VT21/VT22	1 000	
[4]	7	VT1/VT2	800	Increments
		VT6/VT7	400	
		VT10/VT11	200	
		VT14/VT15	100	
[5]	9	VT1/VT2	80	Increments
		VT6/VT7	40	
		VT10/VT11	20	
		VT14/VT15	10	
[6]	11	VT1/VT2	8	Increments
		VT6/VT7	4	
		VT10/VT11	2	
		VT14/VT15	1	

The switches incorporated in item [1] are driven by the polarity bistable, and select the zener diode providing the positive or negative reference voltage source. The operation of this circuit is adequately covered by the description given in paragraph "Reference Supply Sources and Switching" together with the general treatment given in this paragraph, and will not be further considered here. The switches listed in items [2] to [6] are operated by the quantity bistables. All incorporate reference supply load-compensation circuitry and additionally include certain base current stabilising arrangements. A circuit description will only be given for item [2].

Emitter Switches (Board No.3)

In addition to the basic emitter switches this board also carries special circuitry designed to:
1. Stabilise the base current drawn by the emitter switch connecting the reference resistor to the reference supply.
2. Maintain constant loading on the selected reference supply.

The first requirement is necessary if the effective resistance of the emitter switch is to remain the same when connecting the reference resistor to either positive or negative reference supplies. The second requirement is necessary to maintain the output from the reference amplifier at a constant level. Assuming that the 10 000 increment has been accepted, the emitter switch transistor VT15 is cut-on to switch-in the 10 000 increment. If the +10.5 volts reference supply is connected at terminal B6, base current flows from the reference supply via VT15 collector to the base i.e. the transistor is being used in the reverse mode. The effective voltage applied across VT15 base/collector circuit will be 30 volts compared to the 10 volts present when the -10.5 volts reference supply is in use. In the absence of any stabilising circuitry, this 20 volts discrepancy would cause different values of base current, [and hence different emitter switch resistances,] to be obtained when working with positive and negative reference supplies.

The base current stabilising circuit consists of transistors 18 - VT3 and 18 - VT4, the stage being common to all stages requiring stabilisation. Assuming that a positive signal input is applied to the voltmeter, necessitating a positive reference supply, +12 volts output is developed by the polarity bistable at terminal B5 on board No. 2. This signal is applied via 18 - VT3 and 18 - VT4 and provides a -10 volt input to pin 11 - B8. When the 10 000 increment is switched-in, the bistable output from 4 - VT13 applied to 3 - MR53 goes from +12 volts to -20 volts, cutting off the diode MR53. Base current drawn by VT15 is now defined at approximately 20/15k amperes [approximately 1.3mA]. When a negative signal is applied to the voltmeter, the negative reference supply will be utilised. The polarity bistable output B6 will now be negative [-20 volts] and 18 - VT4 will be cut-on. The base current drawn by 3 - VT15 in this circumstance is defined by R31 and VT4 collector current and is designed to be substantially the same as was obtained with a positive signal input.

Constant loading of the reference amplifier output is maintained by compensation circuits associated with each emitter switch. These circuits ensure that when any increment is rejected, a current equivalent to the base current which would have been drawn had the increment been accepted, is taken from the reference supply by another circuit. As opposed to the base current stabilising circuitry which is effective when the reference increment is switched in, the compensation circuits operate when the increment is rejected. The compensation circuit for the 10 000 stage consists of 3 - R33, 3 - MR54 and 3 - VT14, the latter being also common to the remaining stages. When the 10 000 increment is rejected, the collector potential of bistable transistor 4 - VT11 will move to -20 volts, which potential is applied to the junction of 3 - R32 and 3 - R33. The collector of 3 - VT14 is returned to the selected [+ or -10.5 volts] reference supply, which will in either case be more positive than its -10 volts base potential derived from the -10 volt supply via 18 - MR18 and 18 - MR3. The compensation current drawn from the reference supply is defined solely by R33 which is selected to pass a current equal in magnitude to the base current drawn by VT15 when the increment is accepted. The compensation circuits for the remaining stages all operate in the same manner drawing the compensation current through VT14. The purpose of the diode MR54 is to prevent the passage of current through the emitter load resistor R33 when the 10 000 increment is accepted. In this circumstance the junction of resistors R32 and R33 will be held at a potential of +12 volts so that MR5 is reverse-biased. The compensation circuits for the remaining decades operate in a similar manner.

Reference Resistor Network (Board No.17)

The value of each reference resistor is so chosen to inject a known voltage to the balance amplifier input when that resistor is connected to the reference supply by the associated emitter switch. Resistors not connected to reference are shorted to common rail via a second transistor switch. Low value variable resistors [RV1 - RV8] are wired in series with certain reference resistors to permit adjustment to the required degree of accuracy. Additional compensation is provided for the most significant bit emitter switches by potentiometers RV11 to RV14. Considering the major bit [4^4], one of the terminals 15 or 16 may be linked to the reference supply

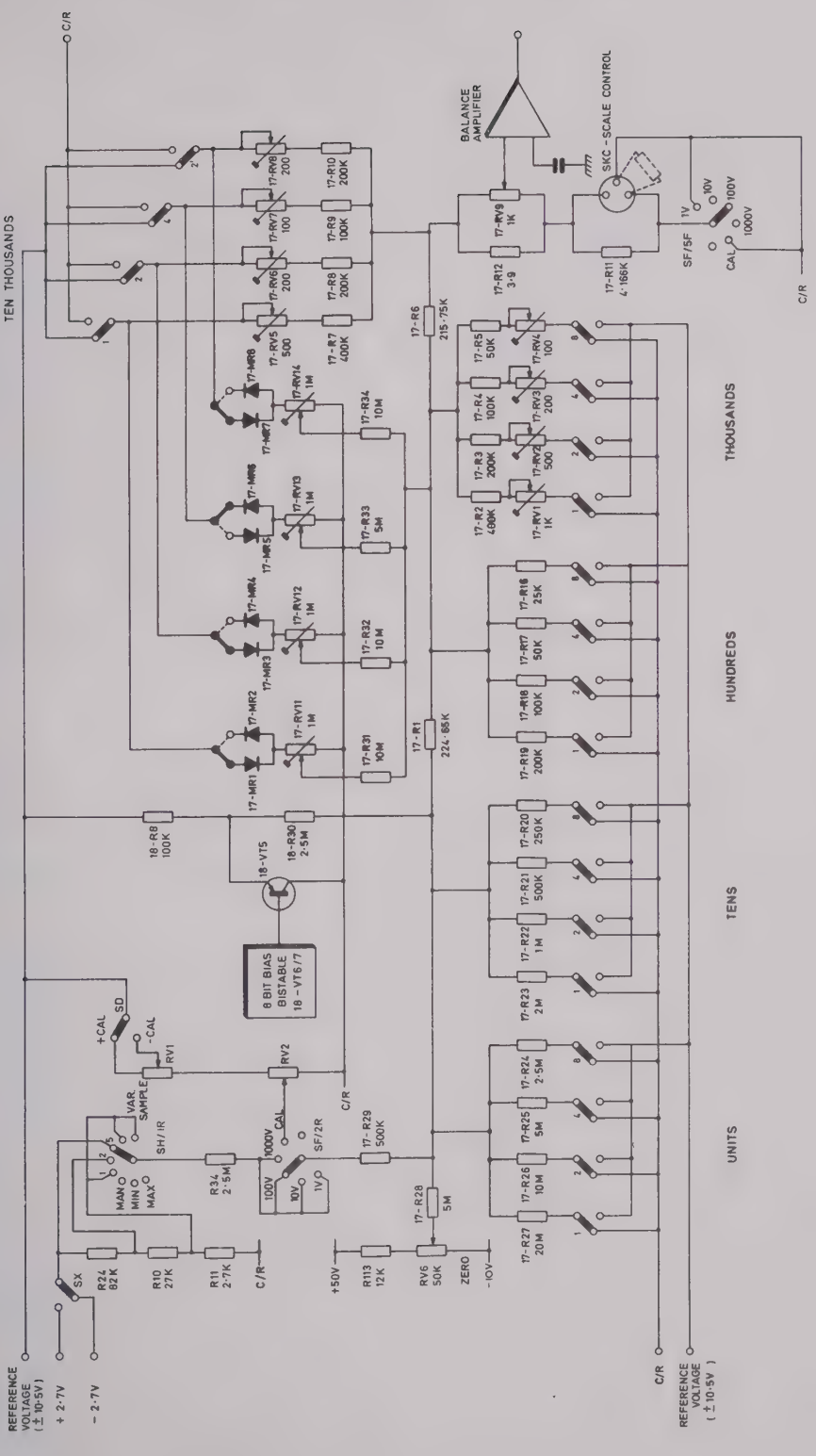


Fig. 4.3 Reference Resistor Network and Bit Bias Circuits

according to whether positive or negative compensation is required. RV13 is thereby connected to either +10.5 volts or -10.5 volts and provides an offset of four bits maximum. Offsets of up to ± two bits may be obtained with RV11, RV12 and RV14.

On the 10 volts range, switchbank SF5F connects the slider of 17 - RV9 direct to common rail to attenuate the available reference voltage in the ratio of 10:1. With the RANGE selector SF set to the CAL. position, and the key-switch SD to the ZERO position, the grid of the balance amplifier input stage V1 is shorted to common rail via SF4R during the drift-correct period. The instrument can now be zeroed by adjustment of potentiometer RV6 [ZERO]. This control, which is connected between the +50 and -10 volts rails, injects a current into the reference summing line to cancel the offset potential developed by the emitter switches.

Decode and Indicator Drivers (Board Nos 7, 9 and 11)

These boards contain the binary to decimal decoding circuitry and the drivers for the relevent neon indicator tubes for the units, tens and hundreds windows. Identical boards are used in each case although only on board No. 7 are diodes MR17 to MR20 operational, hence only this board will be described.

The decode is necessary since the output from the quantity bistables is in Binary Coded Decimal [BCD] form, while the indicator tubes require a decimal drive. The BCD input is applied on eight lines, four of which are always at logical 1 [negative] and four at logical 0 [positive]. Table 4.4 shows the relationships between the BCD and decimal systems used in the LM1867.

One neon indicator tube containing numerals 0 to 9 is driven by ten A1778 transistors arranged in pairs, each pair driving one odd and one even numeral. The neon H.T. supply is derived from a half wave rectifier which provides a positive output commencing at the end of the reference period. The cathode of the selected numeral is returned via its driver transistor to +9 volts, all other cathodes being connected to +80 volts via 120KΩ resistors. As the HT rises towards its positive peak, the neon strikes and the appropriate numeral is displayed.

The outputs from the collectors of the quantity bistables on board 8 are connected to terminals A1 to A4 and B9 to B12. Resistor or diode/resistor networks determine which pair of driver transistors is selected. By deciding whether or not the 100 bistable has been operated, VT3 and VT4 select the transistor in the pair which drives either the odd or even numeral.

Table 4.4 Relationship Between BCD and Decimal

Decimal	BCD [Lines at Logical 1]							
0					1	2	4	8
1	$\overline{1}$					2	4	8
2		$\overline{2}$			1		4	8
3	$\overline{1}$	$\overline{2}$					4	8
4			$\overline{4}$		1	2		8
5	$\overline{1}$		$\overline{4}$			2		8
6		$\overline{2}$	$\overline{4}$		1			8
7	$\overline{1}$	$\overline{2}$	$\overline{4}$					8
8				$\overline{8}$	1	2	4	
9	$\overline{1}$			$\overline{8}$		2	4	
10		$\overline{2}$		$\overline{8}$	1		4	
11	$\overline{1}$	$\overline{2}$		$\overline{8}$			4	

Note: All BCD lines not shown are at logical 0.

Table 4.5 shows the inputs to the decoding network when the 100 bit reference has been selected by the quantity bistable. If the 200 bit reference had also been selected, then the polarities at terminals A1 and A2 would be reversed. Similarly, if the 200 bit reference alone had been selected, then the polarities at terminals A1, A2, A3 and A4 would all be reversed.

Table 4.5 Inputs to Board No. 7

Increment selected by quantity bistable	Terminal	Function	Voltage
100	A3	1	+12V
	A4	$\overline{1}$	-20V
	A1	2	-20V
	A2	$\overline{2}$	+12V
	B11	4	-20V
	B12	$\overline{4}$	+12V
	B9	8	-20V
	B10	$\overline{8}$	+12V

In accordance with the table, as terminal A3 is at +12V, MR1 conducts to apply +12V to the base of emitter-follower VT4. The emitter is held at this voltage which is applied to all drivers controlling even numerals.

MR2 is reverse-biased and the potential at VT3 emitter is held at approximately +9V by the potentiometer R2, R5. All emitters of drivers controlling odd numerals are thus held at this voltage.

MR8 conducts because of the +12V on its anode. MR7 and MR9 are reverse-biased and will not conduct. Similarly, MR10 and MR12 are cut off by the +12V developed at MR11 cathode. +12V at terminal B12 is thus applied to R17. The voltage developed at the junction of R13 and R17 is approximately +10.5V. Since VT5 emitter is held at +12V, it remains cut off. VT8 cuts on as its emitter is at +9V and the one numeral in the tube will therefore be lit.

A consideration of the potentials on R22, R25 and R45 shows that all three are required to be positive before either VT9 or VT12 can conduct. In this case, A1 and thus R22 are at -20V and neither transistor will switch on. Similarly both R28 and R32 must be positive to switch on the drivers for numerals 4 or 5 but as B11 is negative, neither transistor will conduct. VT19 and VT20 will also be held off by the -20V present at terminal B9.

Logic diagram 1 represents the decode circuitry of board No. 7 converted into Solartron Logic Symbols.

In the example given in table 4.5, EMITTER FOLLOWER E1 input is a logical 0. Its logical 0 output inhibits AND gates &1, &3, &5, &7, &9 and thereby numerals 0, 2, 4, 6, and 8 on the display. The AND gates &2, &4, &6, &8, &10 are all enabled by the logical 1 output of E2. The second input of these AND gates is derived from

Table 4.6 Truth Table for Board Nos 7, 9 and 11

Decimal Input	BCD Input [Lines at Logical 1]				Gates Open						Display
0	1	2	4	8	O1	O2	&11	&1			0
1	$\overline{1}$	2	4	8	O1	O2	&11	&2			1
2	1	$\overline{2}$	4	8		O2	&12	&3			2
3	$\overline{1}$	$\overline{2}$	4	8		O2	&12	&4			3
4	1	2	$\overline{4}$	8	O1	O2	&13	&5			4
5	$\overline{1}$	2	$\overline{4}$	8	O1	O2	&13	&6			5
6	1	$\overline{2}$	$\overline{4}$	8		O2	&14	&7			6
7	$\overline{1}$	$\overline{2}$	$\overline{4}$	8		O2	&14	&8			7
8	1	2	4	$\overline{8}$	O1		&15	&9			8
9	$\overline{1}$	2	4	$\overline{8}$	O1		&15	&10			9
10	1	$\overline{2}$	4	$\overline{8}$	O1	O2	&11	&1	&16	&17	0
11	$\overline{1}$	$\overline{2}$	4	$\overline{8}$	O1	O2	&11	&2	&16	&17	1

&11, &12, &13, &14, &15. OR gate O1 is opened by the logical 0 at terminal A2 and supplies one logical 0 input to &11. The second &11 input is derived from terminal B12. OR gate 02 is open because of the logical 0 at terminal B10 and applies the third logical 0 to &11 causing it to open and supply a logical 0 input to &1 and &2. &2 opens and numeral 1 is lit.

&12 is inhibited by the logical 1 at terminal A1, &13 by the logical 1 at B11, &14 by the logical 1 at A1 and B11, &15 by the logical 1 at B9. All other numerals are thus inhibited. The conditions obtaining for other binary inputs from the quantity bistables are shown in Table 4.6

On receiving an input of 10 or 11 from the quantity bistables, a 0 or 1 is displayed and a carry is passed to the next window of the display [10^3]. This only applies for board No. 7. The binary input to board Nos 9 and 11 can not exceed 9 and diodes MR17-20 are not used. It should be noted that when the quantity bistables select a reference bit of 10 or 11, although the display registers 0 or 1, the emitter switches do in fact switch in a reference of 10 or 11 bits.

Decode and Indicator Drivers (Board Nos 3 and 5)

These boards contain the decode circuitry for the 1 000 and 10 000 windows. Since both are similar in operation, only board No. 5 will be described in detail.

10^3 Decode (Board No.5)

Transistors 5 - VT2 and 5 - VT3 prime the drive transistors associated with even or odd numerals in the display tube by detecting whether or not the 1 000 quantity bistable has been operated. When VT2 conducts, the junction of R4 and R6 is clamped to common rail, VT3 is cut off and the junction of R5 and R7 rises to +1.5 volts. If VT2 is cut off, VT3 conducts and the potentials applied to the emitters of the drive transistors are reversed.

The decoding network is such that only one of the resistors R19-R29 is returned to +12 volts via the appropriate diodes at any one instant, all other resistors being held at -20 volts. In this way the appropriate pair of drive transistors is selected.

Considering the conditions at VT5 base when the 1 000 bit reference has been accepted by the quantity bistable, the cathodes of diodes MR19-MR22 are positive and R19 is effectively disconnected permitting MR8 anode to rise positively. Because of the decode network, both R20 and R21 are returned to -20 volts. The anodes of MR9 and MR10 are consequently held at -4 volts and are cut off. VT5 emitter is returned to common rail via VT2 and conducts to illuminate the 1 numeral on the display tube. VT2 base will be held at approximately +1 volt which reduces the base/emitter voltage to +0.5 volt biasing that transistor off.

Logic diagram 2 in conjunction with Table 4.7 illustrates the operation of the decode circuitry for all possible BCD inputs.

As on board No. 7, a carry affects the display only and not the emitter switches.

The $C\overline{2}$ line is also used in the digital carry logic as explained in the paragraph Logic Function 5.

10^4 Decode (Board No.3)

The basic principles of operation are the same as described for the 10^3 decode on board No. 5. However, an additional function has to be performed, that of decoding the 1224 output of the 10^4 quantity bistables into decimal. The relationships between decimal, BCD and 1224 codes are shown in Table 4.9. Table 4.8 illustrates the logical operation of the decoding networks. Logic diagram 3 should be referred to in conjunction with the tables.

Table 4.7 Truth Table for Board No.5

Decimal Input	BCD Input Lines at Logical 1					Gates Open							Display
0	C1	1	2	4	8	O2	O3	&12	O4	&2			0
1	C1	$\overline{1}$	2	4	8	O1	O2	O3	&1	&12	O4	&3	1
			or										
	$\overline{C1}$	1	2	4	8								
2	C1	1	$\overline{2}$	4	8	O2	O3	&15	O5	&4			2
			or										
	$\overline{C1}$	$\overline{1}$	2	4	8	&16	O5	&4					
3	C1	$\overline{1}$	$\overline{2}$	4	8	O1	O3	&1	&15	O5	&5		3
			or										
	$\overline{C1}$	1	$\overline{2}$	4	8								
4	C1	1	2	$\overline{4}$	8	O2	O3	&18	O6	&6			4
			or										
	$\overline{C1}$	$\overline{1}$	$\overline{2}$	4	8	O2	&17	O6	&6				
5	C1	$\overline{1}$	2	$\overline{4}$	8	O1	O2	O3	&1	&18	O6	&7	5
			or										
	$\overline{C1}$	1	2	$\overline{4}$	8								
6	C1	1	$\overline{2}$	$\overline{4}$	8	O2	O3	&19	O7	&8			6
			or										
	$\overline{C1}$	$\overline{1}$	2	$\overline{4}$	8	O1	&20	O7	&8				
7	C1	$\overline{1}$	$\overline{2}$	$\overline{4}$	8	O1	O2	O3	&1	&19	O7	&9	7
			or										
	$\overline{C1}$	1	$\overline{2}$	$\overline{4}$	8								
8	C1	1	2	4	$\overline{8}$	O2	O3	&21	O8	&10			8
			or										
	$\overline{C1}$	$\overline{1}$	$\overline{2}$	$\overline{4}$	8	O1	&22	O8	&10				
9	C1	$\overline{1}$	2	4	$\overline{8}$	O1	O2	O3	&1	&21	O8	&11	9
			or										
	$\overline{C1}$	1	2	4	$\overline{8}$								
10	C1	1	$\overline{2}$	4	$\overline{8}$	O2	O3	&13	O4	&2			10
			or										
	$\overline{C1}$	$\overline{1}$	2	4	$\overline{8}$	O1	&13	O4	&2				
11	C1	$\overline{1}$	$\overline{2}$	4	$\overline{8}$	O1	O2	O3	&13	O4	&3		1
			or										
	$\overline{C1}$	1	$\overline{2}$	4	$\overline{8}$								

Table 4.8 Truth Table for Board No.3

Decimal Input	BCD Input Lines at Logical 1					Gates Open							Display
0	C1	1	2	2'	4	O2	O3	&12	O4	&2			0
1	C1	$\overline{1}$	2	2'	4	O1	O2	O3	&1	&12	O4	&3	1
			or										
	$\overline{C1}$	1	2	2'	4								
2	C1	1	$\overline{2}$	2'	4	O2	O3	&14	O5	&4			2
			or										
	$\overline{C1}$	$\overline{1}$	2	2'	4	O1	&15	O5	&4				
3	C1	$\overline{1}$	$\overline{2}$	2'	4	O1	O2	O3	&1	&14	O5	&5	3
			or										
	$\overline{C1}$	1	$\overline{2}$	2'	4								
4	C1	1	2	2'	$\overline{4}$	O2	O3	&17	O6	&6			4
			or										
	$\overline{C1}$	$\overline{1}$	$\overline{2}$	2'	4	O1	&16	O6	&6				
5	C1	$\overline{1}$	2	2'	$\overline{4}$	O1	O2	O3	&1	&17	O6	&7	5
			or										
	$\overline{C1}$	1	2	2'	$\overline{4}$								
6	C1	1	$\overline{2}$	2'	$\overline{4}$	O2	O3	&18	O7	&8			6
			or										
	$\overline{C1}$	$\overline{1}$	2	2'	$\overline{4}$	O1	&19	O7	&8				
7	C1	$\overline{1}$	$\overline{2}$	2'	$\overline{4}$	O1	O2	O3	&1	&18	O7	&9	7
			or										
	$\overline{C1}$	1	$\overline{2}$	2'	$\overline{4}$								
8	C1	1	$\overline{2}$	$\overline{2}$'	$\overline{4}$	O2	O3	&20	O8	&10			8
			or										
	$\overline{C1}$	$\overline{1}$	$\overline{2}$	2'	$\overline{4}$	O1	&21	O8	&10				
9	C1	$\overline{1}$	$\overline{2}$	$\overline{2}$'	$\overline{4}$	O1	O2	O3	&1	&20	O8	&11	9
			or										
	$\overline{C1}$	1	$\overline{2}$	$\overline{2}$'	$\overline{4}$								
9 and carry 1	$\overline{C1}$	$\overline{1}$	$\overline{2}$	$\overline{2}$'	$\overline{4}$	O1	&13	O4	&2				0

Table 4.9 Relationship between Decimal 1224 Code and BCD

Decimal	1 2 2' 4 Code [Lines at Logical 1]				BCD [Lines at Logical 1]			
0								
1	1				1			
2		2				2		
3	1	2			1	2		
4				4			4	
5	1			4	1		4	
6		2		4		2	4	
7	1	2		4	1	2	4	
8		2	2'	4				8
9	1	2	2'	4	1			8

Note: Maximum count with 1224 code is 9.

Digital Carry Logic

General

The complete logic for the carry functions is shown in logic diagram 4.

The logic performs the following functions.

1. Generates carry signals when the 10^2 stages reach a count of 10 or 11 and passes this information to the 10^3 stages to update the display.

2. Generates carry signals when the 10^3 stages reach a count of 10 or 11 and passes this information to the 10^4 stages to update the display.

3. Generates carry signals when the 10^4 stages reach a count of 9 and a carry is received from the 10^3 stage passing this information to update the 1^5 display.

4. Allows a carry to pass from the 10^2 stages to the 10^4 display when the 10^2 and 10^3 bistables have accepted 1 000 and 9 000 bits respectively.

5. Limits the maximum display to 101999.

Logic Function 1

When the 10^2 quantity bistables have accepted a reference of 1 000 or 1 100 bits, carry information is passed via AND GATE &2 to the 10^3 decode circuits. A carry occurs as previously explained under the heading Decode and Indicator Drivers [Board Nos. 3 and 5.]

Logic Function 2

Ten occuring in the 10^3 quantity bistables causes the $\overline{8}^3$ and $\overline{2}^3$ lines to assume a potential of -20 volts. OR gate O1 opens and supplies one logical 1 input to AND gate &4. The second input to &4 is supplied by the $\overline{8}^3$ line and the gate opens. Its logical 1 output is inverted by INVERTER I3 and again by I2 and applied as a carry signal to the 10^4 decode.

Logic Function 3

The 10^4 quantity bistables are arranged in 1224 code. When a reference of 90 000 bits is selected, the $\overline{1}$ and $\overline{2}'$ lines will both supply a logical 1 to &3 inputs. If a carry now occurs from the 10^3 to the 10^4 stages, then I2 applies the third logical 1 input to &3 which opens. Transistor 18 - VT2 is thus cut off allowing ILP9 to strike and display numeral 1 in the most significant window.

Logic Function 4

If the 10^3 bistables have selected a reference of 9 000 bits and the 10^2 bistables add in 1 000 bits, then a carry is passed from the 10^2 stage to the 10^3 display as before via &2.

A further carry is required to be passed to the 10^4 display since the 10^3 decode will now have been set to 10 000. However, the 10^3 quantity bistables are set to 9 000 and the logic described under the heading Logic Function 2 no longer applies.

Under these conditions, &5 is open and applies a logical 1 to &1. The $\overline{1}^3$ line provides a second logical 1 input to open &1. &1 output opens O1 which applies a logical 1 to one input of &4. &4 second input is derived from the $\overline{8}^3$ line and &4 opens to pass a carry signal to the 10^4 decode circuits via I2 and I3.

This function is prevented if the 10^3 stages have been set to a count of less than 9 since &4 will be inhibited by the logical 0 present on the $\overline{8}^3$ line.

Logic Function 5

Suppose the 10^4 and 10^3 quantity bistables accept their maximum references of 90 000 and 11 000 bits respectively. &6 then has all inputs at logical 1 and opens to limit the 10^2 quantity bistables to a maximum count of 9. The 10^1 and 10^0 stages are limited internally to a count of 9 and the maximum bits of reference which can be selected are shown in table 3.5 in the section Digital Carry Technique.

The 10^2 quantity bistables are contained on board No. 8. Under normal conditions when the input to the voltmeter is less than 101999, +12 volts is applied to terminal 8 - B8 via one ore more of the diodes 18 - MR7 to 18 - MR11. If the 8 bistable is operated, diode 8 - MR1 is cut off by the -20 volts applied to the anode. VT1 base is thus returned to -30 volts via R3 and conducts to bring the potential at the junction of R1 and MR17 to -15 volts. This is applied to the cathode of MR8 via R21 and is sufficient to inhibit the positive pulse from VT6 collector thereby preventing VT7 from selecting the 400 reference bit. MR18 is cut off by the -15 volts on its anode and the positive potential on MR20 cathode cuts off that diode. The 200 bit reference may thus be selected by the 2 bistable.

When &1 opens and the 800 bit reference is selected, diode 8 - MR18 conducts via MR19 and R50 and clamps MR20 cathode to -15 volts. Thus both MR8 and MR20 inhibit the positive set pulses from VT6 and VT9 collectors and neither the 400 nor the 200 bits can be selected. The total reference voltage available has thus been limited to 800 + 100 i.e. 900 bits.

8 Bit Bias Supply

As detailed previously under the heading "Digital Carry Technique", an 8 bit bias is applied to the reference supply while the 10 000 and 1 000 quantity bistables are being interrogated by the ring counter. This is achieved by the bistable 18 - VT6, 18 - VT7. When the ring counter moves to its third position [40 000 bits], the positive pulse at 4 - VT3 collector switches off VT4 generating a positive-going edge on the collector of VT2. This edge is applied to terminal 18p8 to set the bistable such that 18 - VT7 is off and 18 - VT6 on. VT6 collector rises to +12 volts and cuts off VT5. Approximately 8 bits of bias is now applied via 17 - R30 and 18 - R8 to the balance amplifier input. This bias is maintained until the bistable is returned to its quiescent state by the positive-going edge occurring on 8 - VT2 collector as the ring counter sets the 8^2 bistable. 18 - VT5 is then switched on and shorts the 8 bits of bias to common rail.

External Scale Control

The external SCALE CONTROL socket SKC is connected between the reference summing line and signal common rail. It is apparent that any external resistance connected at this socket will be in series with 17 - R11 causing a proportionate increase in the number of reference increments required to produce balance. The inclusion of an external scaling resistance will therefore always increase the instrument reading.

Bit Bias Circuits

A rationalised arrangement of these circuits is also shown in Fig. 4.3. The voltmeter is provided with three resolution modes which, on the 10 volts range for example, enable it to resolve to the nearest 100, 200, or 500 microvolts. If the instrument is to operate with consistent highest accuracy on all ranges, it is necessary to ensure that the instrument turns-over from one reading to another at the correct point. For example, when operating on resolution 1, with the signal input gradually rising from zero, the instrument reading should change from zero to 1, when the input reaches 50 microvolts. Similarly, when operating on resolution 2 or 5, the reading should turn-over when the input signal reaches 100 or 250 microvolts respectively. The correct turnover points are established by the injection of suitable bias voltages into the reference summing line from a stable 2.7 volts supply of opposite polarity to the reference supply. The bias voltages for the 1, 2 and 5, resolution modes are developed across R11, R11/R10, and R11/R10/R24, respectively, and applied to the reference summing line via SH1R, SF2R, and resistor 17 - R29. Switch SX, which selects the bias voltage source, is shown in Fig.

4.3 as a simple single-pole, change-over contact, but is in fact an electronic switch controlled by the polarity bistable.

The ± 2.7 volts supplies are derived from a resistive network R36, R37, R38 [board No. 1] which divides down the output from one side of the polarity bistable [2 - VT3]. Assuming a positive signal input to the voltmeter, transistor 2 - VT4 of the polarity bistable will conduct, and the output developed across VT3 collector load R5 will stand at -20 volts. This signal is applied to the cathode of diode 1 - MR7, which conducts to apply the -20 volts potential across the voltage divider 1 - R38, 1 - R36. An output of the order of -2.7 volts is now developed across R36, and applied via terminal B4 to the resistive chain R11, R10, R24 developing the bias voltage. Conversely, for a negative signal input, the control signal at VT3 collector will go to +12 volts, which in turn forward biases 1 - MR6 so that an output of +2.7 volts is now developed across R36.

In order to ensure positive lock-out on maximum and minimum reading operation, it is necessary to employ a modified biasing arrangement. For these operational modes a signal is taken from the output, terminal 1 - B11, of the polarity bistable. For positive and negative signal inputs to the instrument, the potential appearing at this terminal and applied to the bias network will be -20 volts and +12 volts respectively. The resistive network R13, R14, R12, on board No. 1 providing the bias input on the maximum position is associated with the -10 volts supply, whilst the network R2, R3, R8 for the minimum mode is associated with the +12 volts supply. Assuming a -20 volts input from terminal 1 - B11, diode MR1 will be cut-off, and MR2 will conduct to apply the -20 volts potential across R13 and R12 and develop a bias of -1.5 volts at their junction. This is applied to the reference summing line via switchbank SH1R and SF2R. The other bias voltages are obtained in a similar manner, their values being as listed in Table 4.10.

Table 4.10 Max/Min Bias Voltages

Mode	Signal Input Polarity	Bias
Max. reading	+	-1.5V [1½- bit]
	-	-0.4V [½- bit]
Min. reading	+	+0.4V [½- bit]
	-	+1.5V [1½- bit]

To ensure correct operation of the trip facility on the 1 volt signal range, and the maximum and minimum reading modes, it is essential that bias is applied only for the duration of the digitisation period. Accordingly, transistor 19 - VT14 is driven on its base with a signal derived from the collector of 19 - VT12, which in turn is driven from the output of the stable ring stage 19 - VT1. In the quiescent condition, the instrument will rest in the stable state with VT1 conducting. In this circumstance, the positive signal developed at its collector will cut-off VT12, which as a result will apply a potential of -5 volts to VT14 base. The bias voltage will now be shorted to signal common rail via VT14 emitter/collector path. On the commencement of a ring cycle [digitisation period], the ring start bistable transistor 19 - VT1 will be cut-off on the incidence of the negative start pulse to 19 - VT3 base, and the negative signal developed at its collector will cut-on VT12, which in turn will apply a cut-off potential of +12 volts to the base of VT14. The bias voltage will now be applied to the reference summing line. At the end of the digitisation period when the ring is returned to the stable state with VT1 conducting the -5 volts potential will be re-applied to the base of VT14 which will pass current to short the bias voltage to signal common rail.

External Access to Bistable Outputs

A modified BCD output, decimal point information, polarity and print command signals are extended to an internal 50-way socket SKA. The use of these outputs necessitates the fitting of certain external circuitry, which is described in paragraph 'Information Out'.

Display Blanking

Display blanking during digitisation is achieved by energising the numerical indicator tubes with a half-wave rectified supply, which goes positive to provide the firing potential for the tubes only during the drift-correct period. The negative half-cycle, which takes place during the reference period, is suppressed by normal rectifier action.

Resolution Control

General

Resolution control is effected by inhibiting the operation of certain unit bistables, thus ensuring that the reference increment associated with these bistables is rejected.

1 Bit Resolution (Board No.12)

When operating with 1-bit resolution the extreme right-hand window moves in units, representing 100μV increments on the 10 volt range. All bistables are operative, and the VT11 collector/VT13 base coupling resistor R20 is connected externally via terminal A8, switchbank SH2R and terminal A3.

2 Bit Resolution (Board No.12)

When operating with 2-bit resolution the extreme right-hand window moves in 'twos', representing 200μV increments on the 10 volt range. To achieve this condition, the unit bistable VT11/VT13 is held off by the application of a negative [-30 volts] potential to the base of VT13 via terminal A8, R20 and switchbank SH2R. The unit bistable is thus permanently locked in the 'reference rejected' condition [VT13 on, VT11 off], so that the instrument operates with a resolution of 2-bits.

5 Bit Resolution (Board No.12)

When operating with 5-bit resolution, the right-hand window moves in 'fives' representing 500μV increments on the 10 volt range. It is therefore only required that the 4 and unit bistables be capable of operation. Accordingly, the 8 and 2 units bistables are locked-out by disconnecting the gate-line from the ring reset diodes MR4 and MR11, via switchbank SH3R. In this circumstance, the negative reset pulses generated by the ring counter stages VT3 and VT9 at the end of their period of conduction, cannot be absorbed by the gate line but must be applied to the related quantity bistables to return these to the 'off' [reference rejected] condition. The unit reset diode MR15 is also returned to the open-circuited gate-line, thus removing normal gating control from the unit bistable to enable it to be controlled from the four units bistable VT5/VT7. For this purpose, the base of VT13 is connected to the collector of VT5 via terminal A8, resistor R20, switchbank SH2R, and terminal B11. If now the 4 units increment is accepted VT5 of the 4 units bistable will be conducting and its collector will stand at a potential of approximately +12 volts. The signal is applied to the base of VT13 via switchbank SH2R and R20 to cut-off that transistor and thereby hold the bistable in the reference accepted condition with VT11 conducting. Conversely, if the 4 units increment is rejected, the negative potential appearing at the collector of VT5 will cut-on VT13 to set the unit bistable to the reference rejected condition.

Power Supply System

General

The mains transformer is provided with a split primary winding capable of parallel or series connection to accomodate mains inputs within the range 100 - 125 volts or 200 - 250 volts. The transformer has six secondary windings and provides the following supplies:-

1. +50 volts d.c. stabilised.
2. +20 volts d.c. stabilised.
3. -10 volts d.c. stabilised.
4. -30 volts d.c. stabilised.
5. +12 volts d.c. stabilised.
6. +150 volts half-wave rectified.
7. A half-wave rectified, smoothed HT supply for the decimal point neons from which a +80 volts supply is derived.
8. 6.3 volts a.c. supply to synchronous chopper relays.

With the exception of the power transistors, large smoothing capacitors and rectifiers, all components associated with these circuits are carried on board No. 13.

+50 Volts Stabilised DC Supply

The output at transformer terminals 11, 12, 13 is full-wave rectified by MR1 and MR2. Stabilisation is effected by an emitter-coupled differential amplifier VT5, VT6, which drives a series power transistor VT1 via an intermediate amplifier 13 - VT1. The sample signal is developed in the resistive chain R9, RV1, R8 and the line output potential is set to +50 volts by adjustment of potentiometer RV1.

+20 Volts Stabilised DC Supply

The reference potential is taken from the +50 volts rail. The +20 volts rail, connected to the emitter of VT3, is maintained by the zener references MR5 and MR6.

+12 Volts Stabilised DC Supply

The +50 volts stabilised supply is divided down in the resistive chain formed by R24 and the reference circuit MR3, MR4. The +12 volts supply is derived via a high current gain stage 13 - VT11 and VT4.

-10 Volts Stabilised DC Supply

This circuit employs two emitter-coupled differential amplifiers, VT8/VT9 and VT2/VT4, the first of which is referred to the +50 volts stabilised d.c. supply. The series power transistor VT2 is driven direct from the collector of 13 - VT2.

-30 Volts Stabilised DC Supply

The output at transformer terminals 20, 21, 22, is full-wave rectified by MR3 and MR4. The sampling potentiometer R12, R13, is connected between the +50 volts and -30 volts rails, and the error signal amplified by VT10, whose emitter is referred to the -10 volts stabilised rail. Output from the collector of VT10 is applied to the base of the intermediate amplifier VT7, which in turn drives the series control element VT3.

+150 Volts Supply

The output at mains transformer terminals 29 and 31 is half-wave rectified by MR10. Only a small degree of smoothing is applied by C1 [0.47μF], since a half-wave output is essential for the operation of the blanking function. Reference paragraph Display Blanking.

+80 Volts Supply

The output at mains transformer terminals 29 and 30 is half-wave rectified by MR9, and applied to the decimal point neon indicator lamps via R25. The supply is also taken, via R35, to provide +80 for the decoding circuits. Smoothing is applied by C6.

Mains Synchronising Outputs

The phase-retarded mains synchronising drive to the ring start circuit and reference amplifier choppers is taken from R8/C15 and R86/C27, which are energised from the a.c. output at mains transformer terminals 20, 21 and 22.

AC Supply

The mains transformer provides one a.c. output at 6.3 volts r.m.s. for energising the synchronous chopper relays RLA/1 and RLB/1.

Earthing Arrangements

Switch SB enables the instrument to be operated with a mains earth or external earth as required. Resistor R14, value 10 ohms, is a current limiter to protect the instrument wiring loom in the event of a short circuit between any supply rail and earth.

LOGIC SYMBOLS

Introduction

The symbols in this supplement permit the logic of complicated switching circuits to be depicted without the use of detailed graphical symbols for the individual components and without reference to comprehensive circuit operation notes.

Throughout this standard the symbols 0 and 1 are used to represent the values of signals which can have only two states.

The table of combinations describes the active input/output conditions of the basic logic functions (i.e. HIGH more positive and LOW relatively less positive). When using positive logic, logical 1 represents HIGH and logical 0 represents LOW When using negative logic, logical 1 represents LOW and logical 0 represents HIGH.

Input/output signals are designated as follows:

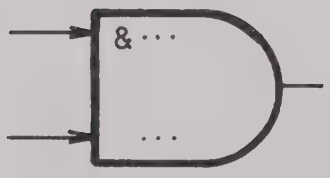
	INPUT	OUTPUT
DC HIGH LEVEL		
DC LOW LEVEL		

Symbol Identification

Symbols are identified in the following manner:-

1. TYPE OF FUNCTION AND REFERENCE NUMBER

DISCRETE COMPONENTS



2. Where four or more inputs feed an 'AND' or 'OR' gate they are shown thus.

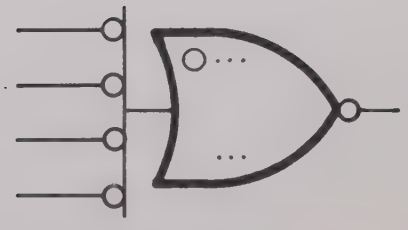


Table 4.11 Logical Elements

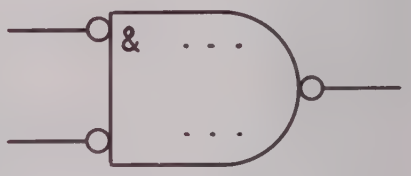
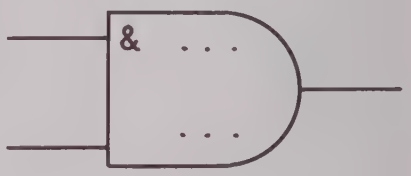
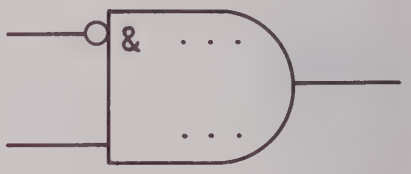
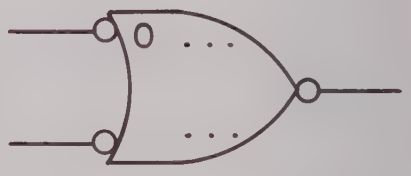
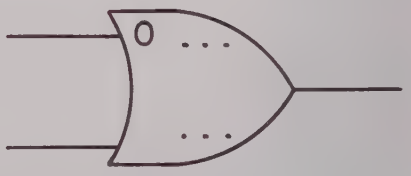
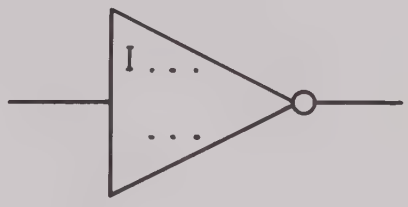
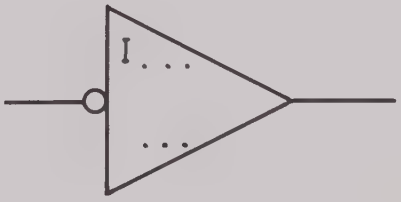
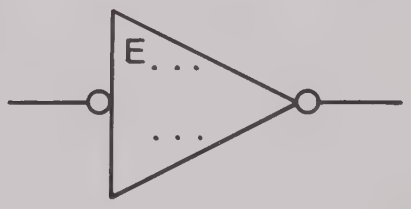
Logic Element	Symbol
"AND" GATE (&) The output signal represents 1 if, and only if, all the input signals represent 1.	
"AND" GATE (&) The output signal represents 0 if, and only if, all the input signals represent 0.	
"AND" GATE (&) The output signal represents 0 if, and only if, the low input represents 1 and the high input represents 0.	
"OR" GATE (O) The output signal represents 1 if any one or more of the input signals represent 1.	
"OR" GATE (O) The output signal represents 0 if any one or more of the input signals represent 0.	

Table 4.11 (Continued) Logical Elements

Logic Element	Symbol
INVERTER (I) The output signal represents 1 when the input signal represents 0. (This symbol is used when a logical 1 is required to operate the succeeding circuit).	
INVERTER (I) The output signal represents 0 when the input signal represents 1. (This symbol is used when a logical 0 is required to operate the succeeding circuit).	
EMITTER FOLLOWER (E) The output signal represents 1 when the input signal represents 1.	

SECTION 5
PHYSICAL DESCRIPTION

General

The LM1867 contains nineteen printed circuit boards as listed in table 5.1. Fifteen of these are plug-in fitments, two are permanently wired in and two are wired to a sub-chassis.

Table 5.1 Printed Circuit Board Nos and Functions

Position	Board Part No.	Function	Mounting
1	AD18679001	Start gate Reference supply source and emitter switches Reference amplifier output clamp	Plug-in
2	AD18679002	Polarity and delay stages of ring counter Polarity bistable Decision logic Decision gate Chopper drive	Plug-in
3	AD18679003	10 000s decode and emitter switches Display tube	Plug-in
4	AD18679004	10 000s quantity bistables and associated ring stages 3 to 6	Plug-in
5	AD18679005	1 000s decode and emitter switches Display tube	Plug-in
6	AD18679006	1 000s quantity bistables and associated ring stages 7 to 10	Plug-in
7	AD18679007	100s decode and emitter switches Display tube	Plug-in
8	AD18679008	100s quantity bistables and associated ring stages 11 to 14	Plug-in
9	AD18679007	10s decode and emitter switches Display tube	Plug-in
10	AD18679010	10s quantity bistables and associated ring stages 15 to 18	Plug-in

Table 5.1 (continued) Printed Circuit Board Nos and Functions

Position	Board Part No	Function	Mounting
11	AD18679007	1s decode and emitter switches Display tube	Plug-in
12	AD18679012	1s quantity bistables and associated ring stages 19 to 22	Plug-in
13	AD18679013	+50V, +20V, +12V, -10V, -30V supplies	Plug-in
14	AD18679014	Reference amplifier	Plug-in
15	AD18679015	Input and balance amplifier electrometer valves	Wired in as part of Input Amplifier sub-chassis
16	AD18679016	Input and balance amplifier output stages	Wired in as part of Input Amplifier sub-chassis
17	AD18679017	Reference resistors Reference amplifier input and feedback resistors	Wired in
18	AD18679018	100 000 decode and neon driver Carry logic for 10 000 decode 101999 limiting gate 8 bit bias logic Emitter switch base current stabilising circuitry Positive and negative display driver Standard cell normalising circuitry	Wired in
19	AD18679019	Quantity bistables reset circuit Sample bistable Variable sample logic Ring start bistable 4kHz Oscillator	Plug in

Preset Controls

In addition to the controls on the front panel, there are twenty three presets mounted internally and listed in Table 5.2.

Table 5.2 Preset Controls

Component Reference	Function	Location
1-RV1	Set +ve input impedance	Board 1
1-RV2	Set -ve input impedance	
13-RV1	Set +50V supply	Board 13
14-RV1	Reference amplifier slope	Board 14
16-RV1	Input amplifier gain	Board 16
17-RV1	1	Board 17
17-RV2	2 10^3 Reference bits	
17-RV3	4 fine adjustment	
17-RV4	8 [linearity controls]	
17-RV5	1	
17-RV6	2 10^4 Reference bits	
17-RV7	4 fine adjustment	
17-RV8	2' [linearity controls]	
17-RV9	1V range adjustment	
17-RV10	Reference Amplifier coarse gain adjustment [i.e. 10V range adjustment]	
17-RV11	1	Board 17
17-RV12	2 10^4 emitter switches compensation	
17-RV13	4 [linearity controls]	
17-RV14	2'	
18-RV1	Calibration setting	Board 18
18-RV2		
RV1	Input attenuator 100V range adjustment	Right side chassis
RV2	Input attenuator 1 000V range adjustment	

CAUTION: The controls listed in Table 5.2 are all set at the time of factory test and must not be re-adjusted when the instrument is installed.

Dismantling Instructions

Removal of Instrument Case

[1] Disconnect mains lead from supply source.
[2] Remove the four screws from the right and left hand edges of the front panel.
[3] Withdraw the chassis from the case in a forward direction, threading the mains cable through the aperture at the rear.
[4] Remove eight screws from around the edge of the perforated protective cover and remove from the top of the instrument.

Removal of Board Nos 1 to 12 and 19

These thirteen boards are mounted immediately behind the front panel.
[1] Unscrew the two fasteners at the ends of the display hood covering the neon indicator tubes, and remove the upper half of the hood.
[2] Withdraw the required board from its socket by a steady pull in an upward direction, taking care not to apply lateral pressure.

Removal of Board Nos 13 and 14

These boards are situated at the right centre to the rear of the chassis and may be removed as in [2].

Refitting of Boards

Check that the edge connector is clean and that the board is being returned to the correct socket. After insertion, check that the board is driven fully home along the entire length of the socket.

Removal of Balance Amplifier Sub-Chassis

This amplifier is built as a plug-in, screened sub-unit and is located at the right-centre of the main chassis.
[1] Turn main chassis upside-down, remove one 6BA screw from each corner of the screened sub-unit, and lift-off cover plate.
[2] Pull-off top caps from electrometer valves V1 and V2.
[3] Turn-over main chassis to normal operational position to give access to upper-side of screened sub-unit.
[4] Remove one 6BA securing screw from each corner of the upper-side of the screened sub-unit.
[5] With a direct upward pull, withdraw sub-unit from socket, and lift clear of main chassis.

Removal of Cover Plate from Resistor Box

The precision reference resistors are contained in a box at the right-hand rear corner of the main chassis.
[1] Remove one self tapping securing screw from each corner of the box and lift-off cover plate to expose resistors.

Removal of Chopper Relays

The chopper relays are mounted at the right-hand side of the chassis, just forward of the balance amplifier sub-unit. Both relays are carried in B7G valve-holders, from which they can be removed by a direct upward pull after releasing the retaining valve cans.

Removal of Input Attenuator Resistor Box

The box is mounted in the forward right-hand corner of the instrument chassis.

[1] At the range selector, unsolder the four wires connecting the resistor box to the selector switch wafers.
[2] At the right-hand forward side of the instrument, remove the four 6BA screws securing the box-mounting plate to the pillar mounts.
[3] Holding the mounting plate, withdraw the box through the aperture in the right-hand side of the main chassis.

Removal of Indicator Tubes

Five tubes are fitted and mounted on the boards as listed in Table 5.3.

Table 5.3 Location of Indicator Tubes

Indicator	Board Position
10 000	3
1 000	5
100	7
10	9
1	11

[1] Remove the appropriate board following the directions given in paragraph 'Removal of board Nos 1 to 12 and 19'.
[2] Extract the tube from the holder with a straight pull.

The 100 000, decimal point, positive and negative neon indicators are mounted in the display moulding. Access to the positive and negative indicators may be gained through the cut-out in the left side chassis. After unsoldering the leads, the neon tube may be removed by a direct pull.

To remove the 100 000 indicator, the upper half of the display hood must first be removed as directed in paragraph 'Removal of board Nos 1 to 12 and 19'. This exposes the connections to the neon which may be removed by a direct pull after unsoldering.

To remove the decimal point indicators, it is first necessary to remove several adjacent boards before the relevant neon is exposed [see the directions in paragraph 'Removal of board Nos 1 to 12 and 19']. After unsoldering the appropriate two leads from the tag strip, the neon may be removed by a direct pull.

Servicing by Renewal of Printed Circuit Boards

The substitution of a new board in place of a defective one is permissable, subject to the following exceptions:-

Board Nos	AD18679001
	AD18679003
	AD18679005
	AD18679007 [Position 7 only]
	AD18679014
	AD18679015
	AD18679016
	AD18679017
	AD18679018

Renewal of any one or more of these boards will invalidate the calibration of the instrument and require the use of specialised test equipment.

SECTION 6
TEST & CALIBRATION PROCEDURES

INTRODUCTION

The LM1867 voltmeter is essentially a 0.001% accurate instrument. Factory tests are conducted using highly accurate equipment in a carefully controlled environment. If the calibration is not to be invalidated, it is imperative that only the controls described in the following procedure are adjusted. This abridged test procedure is primarily intended to allow simple non-critical adjustments to be made and to permit the principal parameters to be verified. If the accuracy is suspect, the voltmeter should be returned for re-calibration.

To avoid the possibility of invalidating the BCS Certificate, it is recommended that no internal preset controls are disturbed on LM1867C instruments.

CHECK OF MAIN FUNCTIONS

The following abbreviated procedure may be adopted as a general operational check of the voltmeter.

[1] After the instrument has warmed up, with MODE SWITCH set to RESOLUTION 1, check for approximately correct display on both polarities and on all ranges.

[2] Check for correct display of all digits.

[3] Short circuit the input leads and set RANGE SWITCH to CAL. Adjust the ZERO CAL POT. on the front panel for 0.00000. Check that zero is displayed on all ranges with FILTER on all positions.

[4] Check that a completely steady reading can be obtained on the 1 volt range on both polarities at high readings.

[5] Using the lead supplied, check the scale facility by shorting the leads and noting that the displayed reading increases by a factor of 10.

[6] With MODE SWITCH set to MAX, check that the display follows an increasing positive but not a decreasing positive input.

[7] With MODE SWITCH set to MIN, check that an increasing negative reading only is followed. Check that when the RESET button is pressed, the reading returns to zero if the input has been removed.

[8] Set MODE SWITCH to RESOLUTION 1 and the RANGE SWITCH to CAL. Accurately set postiive and negative CAL readings by means of the appropriate front panel pots.

[9] With MODE SWITCH on MANUAL SAMPLE, RANGE SWITCH on CAL and the CAL SWITCH set alternately to the positive and negative positions, check that the display changes only when the MANUAL SAMPLE button is pressed.

[10] Check the operation of the RESOLUTION 2 and 5 positions of the MODE SWITCH by applying an input with the RANGE SWITCH on the appropriate position and noting that the display moves in 2 or 5 digit steps respectively

[11] Set MODE SWITCH to VARIABLE SAMPLE 0-150 secs. with the potentiometer fully clockwise. Short circuit the input leads and set the RANGE SWITCH to CAL and the CAL SWITCH to the positive position. When the reading changes from zero to the positive CAL reading, commence timing and release CAL SWITCH. Check that the display returns to zero in approximately 3 minutes.

[12] Select the 10 volt range and obtain a display above 10 volts. The reading should not change by more than two digits when the polarity of the input is reversed. Repeat on the 1 volt range.

[13] Using an accurate voltage source, make spot accuracy checks at approximately 1/3 of full scale and at full scale on each range and each polarity.

DETAILED TEST PROCEDURE

Recommended Test Equipment

Solartron Sine Wave Oscillator CO 546
Solartron Feedback AC Voltmeter VF 252
Six dial Kelvin Varley Decade Box
10V Humfree DC Supply [e.g. a battery]
500V Megger
Variable mains supply [e.g. a Variac]
Solartron Oscilloscope CD 1400
100V DC Supply
100KΩ 2% resistor
10MΩ resistor

Detailed Tests

Filter Checks

Switch off LM1867 and connect the input leads to the CO 546 oscillator set to provide an output of 10 volts at 50Hz. Connect VF 252 voltmeter to pin 1 on input chopper RLA for monitoring purposes. Set FILTER [SG] to the 60dB position and check that the VF 252 reading reduces by not less than 60dBs.

By altering the setting of the CO 546, check that the maximum attenuation indicated by the VF 252 occurs at 50Hz ± 1Hz.

Repeat the above procedure for the 80dB and 90dB positions.

Set the CO 546 to 100Hz and check the 90dB 100Hz position.

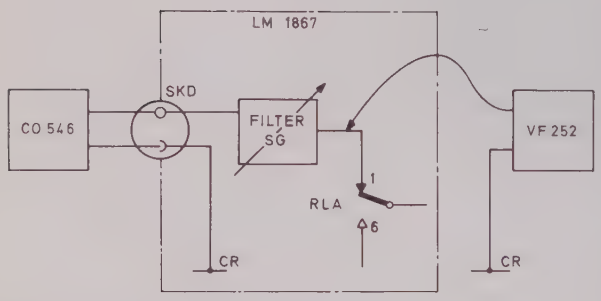


Fig. 6.1 Filter Checks

Preliminaries

Set MAINS VOLTAGE SELECTOR to the 100 volt position and connect the LM1867 to a 100 volt a.c. supply. Check with the Avometer on mains transformer T1 terminals 25 and 26 that RLA and RLB supply voltage is 6.3 volts a.c. ± 0.4 volts. Repeat for all other positions of the MAINS VOLTAGE SELECTOR adjusting the a.c. supply as necessary.

Set the MAINS VOLTAGE SELECTOR to the 240 volt position and adjust the a.c. supply to 240 ± 3 volts. Set LM1867 RANGE SWITCH [SF] to the 10 volt position. Set MODE SWITCH [SH] to RESOLUTION 1, FILTER [SG] to OUT and INPUT LOW [SB] to MAINS EARTH.

Supply Voltages

Adjust RV1 on board No. 13 so that the 50 volt line measures 50 volts ± 0.1 volt. [Tap RV1 to ensure it is fully settled.] Check all rails in accordance with Table 6.1.

Table 6.1 Voltage Rail Tolerances

Rail	Tolerance	peak to peak ripple
+50V	±0.1V	3mV
+20V	+19.8V ± 1V	10mV [with MODE SWITCH [SH] in MANUAL position]
+12V	+12.5V ± 0.6V	15mV
-10V	-10.1V ± 0.3V	1mV
-30V	-29.9V ± 0.7V	10mV
+80V	+80V ± 8V	Unspecified
+150V	+150V ± 16V	Unspecified

Reference Zener and Oven

Check that the voltage across MR14 on board No.1 lies between 6.16 volts and 6.55 volts. If below 6.16 volts, a 390Ω resistor may be added in series with RV10 on board No. 17.

Check that the voltage across the diode oven is nominally 25 volts d.c.

Check that during the oven warm-up period [approximately 1½ minutes] the reading obtained with the CAL SWITCH [SD] depressed changes by less than 250 digits.

Calibration Pot. Centralisation

Set RANGE SWITCH [SF] to CAL. Set the positive and negative CAL pots on the front panel to their mid-positions. Set the CAL SWITCH [SD] to the positive position and adjust RV10 [board No. 17] to give a reading of +1.01900 ± 20 digits.

Zero Check

Short circuit the input leads. Place a metal cover on top of the LM1867 and connect it to chassis. Check on the 1 volt and 10 volt positions of the RANGE SWITCH [SF] that a reading of at least ±4 digits can be obtained by adjustment of the ZERO CAL. POT on the front panel [RV6].

Set the RANGE SWITCH [SF] to CAL and adjust RV6 so that the reading just changes from +0.00000 to -0.00000. Check that zero is displayed on all other settings of the RANGE SWITCH [SF].

Input Amplifier Gain Adjustment

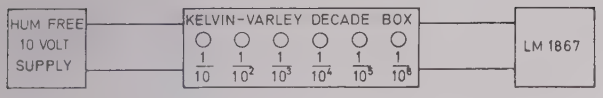


Fig. 6.2 Input Connections

Set the RANGE SWITCH [SF] to 1 volt and MODE SWITCH [SH] to RESOLUTION 1. With the Decade Box set to maximum connect the 10 volt supply and the LM1867 input leads as shown in Fig. 6.2. Adjust the supply so that the LM1867 displays 0.10000V ± 0.00010V. [The 10 000 dial on the Decade Box will now move in 10μV steps.] Set Decade Box to 000500 and CD1400 oscilloscope to 5V/cm. Connect the CD1400 as in figure 6.3.

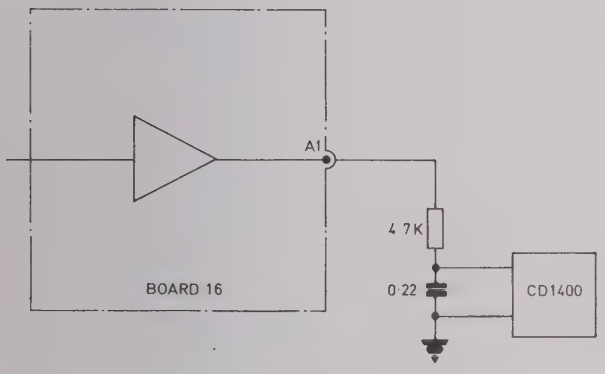


Fig. 6.3 Input Amplifier Gain Adjustment

Set the MODE SWITCH [SH] to MANUAL SAMPLE and examine the waveform which occurs during the digitisation period when the MANUAL SAMPLE button [SC] is pressed [fig. 6.4]. Adjust the ZERO CAL POT [RV6] on the front panel so that this waveform is central about 0V. Adjust RV1 on board 16 so that when the input is increased by 10μV, the waveform of fig. 6.5 is seen and when the input is reduced by 10μV the waveform of fig. 6.6 is observed [i.e. the amplifier gain is set to 10^6].

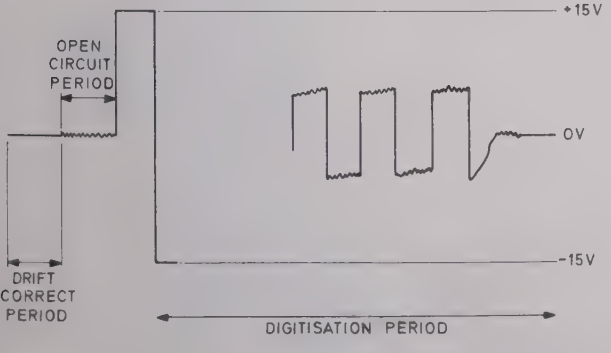


Fig. 6.4 Input Amplifier – Output Waveform

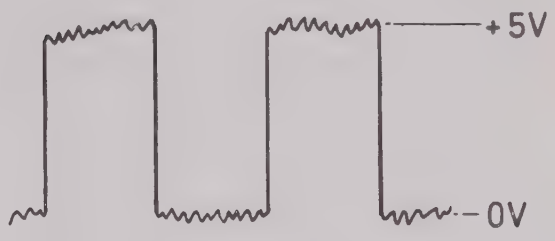


Fig. 6.5 Input Amplifier – Increasing Input

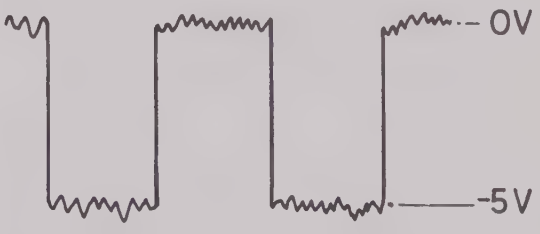


Fig. 6.6 Input Amplifier – Decreasing Input

Reference Amplifier Slope

Connect together the input high and low leads. Set the MODE SWITCH [SH] to MANUAL, RANGE SWITCH [SF] to 1V and FILTER SWITCH [SG] to 60dB. With the oscilloscope connected as in fig. 6.3, examine the waveform during the digitisation time. Adjust the front panel ZERO CAL POT [RV6] so that the waveform occurring during the ring period is balanced about 0 volts. Connect an input as in fig. 6.2 and obtain a display between +1.00000 and full scale. Adjust the SLOPE POT [RV1 on board No. 14] so that the slope over the ring period does not exceed 8 volts.

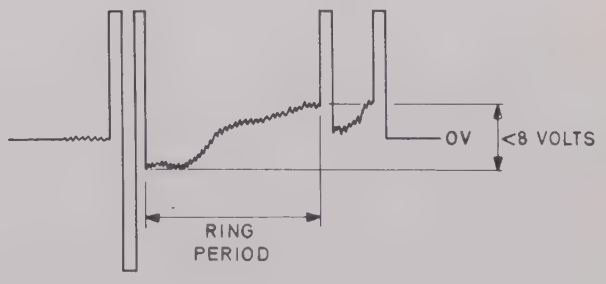


Fig. 6.7 Slope Adjustment

Obtain a display between -1.00000 and full scale and check that the slope is within specification, adjusting RV1 if necessary.

Input Impedance

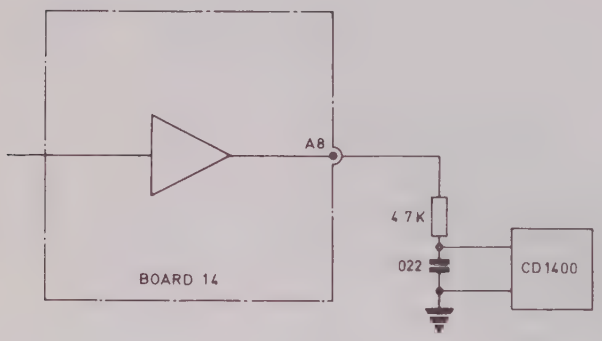


Fig. 6.8 Reference Amplifier Monitoring

Set RANGE SWITCH [SF] to 10 volts, MODE SWITCH [SH] to RESOLUTION 1 and FILTER [SG] to 90dB. Apply an input of approximately +10 volts and monitor the Reference Amplifier as in fig. 6.8 where a waveform similar to that shown in fig. 6.9 will be present. Adjust RV1 on board No. 1 until the difference A between the signal period and the open circuit period is less than 50mV [spikes may be disregarded].

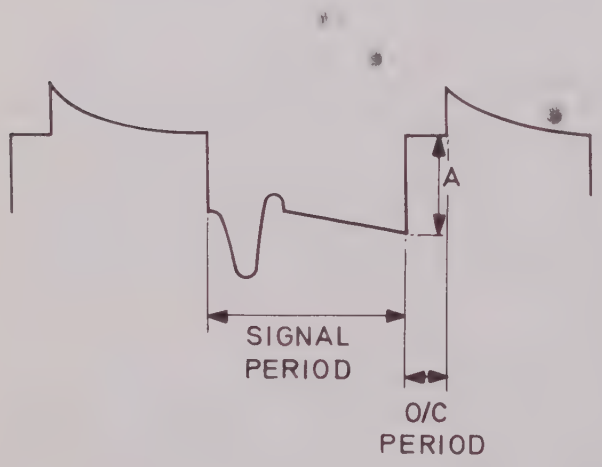


Fig. 6.9 Reference Amplifier – Output Waveform

Apply an input of -10 volts and adjust RV2 on board No. 1 fully anti-clockwise. Note the reading on the LM1867. Insert a 10MΩ resistor in series with the high input lead and check that the new reading is less than 25 digits lower than the original.

Apply an input of +10 volts and check with the 10MΩ resistor as in the preceding paragraph.

Insulation and Floating Checks

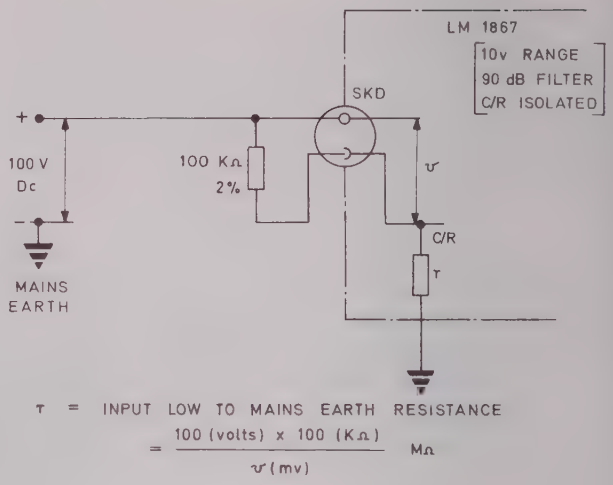


Fig. 6.10 Insulation and Floating Check

Remove all plug in boards and unsolder one end of C2. Set INPUT LOW SWITCH [SB] to ISOLATED. Check with a 500 volt Megger that the insulation between Mains Earth and Common Rail is infinite, using a 1MΩ limiting resistor in series with one of the leads.

Resolder C2 and replace plug in boards. Connect a 100KΩ 2% resistor between C/R and the Signal Input and apply approximately +100 volts as shown in fig. 6.10. Set RANGE SWITCH 9 [SF] to 10 volts, FILTER to 90dB, MODE SWITCH to RESOLUTION 1 and INPUT LOW SWITCH [SB] to ISOLATED. The LM1867 should now read less than 0.0400.

Disconnect the 100 volt supply and remove the 100KΩ resistor. Short the input leads together. Set FILTER [SG] to OUT. Select each range in turn by means of RANGE SWITCH [SF] and check that on the 10 volt and 1 000 volt positions there is a steady reading of 0.00000. On the 1 volt and 100 volt positions, a reading of not more than +0.00008 should be displayed which changes to 0.00000 when the FILTER [SG] is switched in.

Mains Variation

Set RANGE SWITCH [SF] to CAL and FILTER [SG] to OUT. Depress CAL SWITCH [SD] to obtain a positive reading. Vary the AC mains input voltage by ±24 volts and check that the reading does not change by more than 3 digits.

Repeat with a negative cal. reading.

Positive to Negative Check

With LM1867 set up as for the preceding check, depress the CAL SWITCH [SD] to obtain a positive reading and adjust the POSITIVE CAL POT on the front panel [RV4] to display the positive CAL reading. Adjust the NEGATIVE CAL POT [RV5] to display the negative CAL reading when the CAL SWITCH [SD] is set to the negative position. Set MODE SWITCH [SH] to MANUAL SAMPLE and CAL SWITCH [SD] to the positive CAL position. Press MANUAL SAMPLE button [SC] to display the positive CAL reading. Set CAL SWITCH [SD] to the negative CAL position and press the MANUAL SAMPLE button [SC]. The difference between this and subsequent samples should be not greater than 5 digits.

Repeat the above having set up a negative CAL reading on the display and subsequently setting the CAL SWITCH [SD] to the positive CAL position.

Display

Set RANGE SWITCH [SF] to 10 volts and MODE SWITCH [SH] to RESOLUTION 1. Vary the input voltage to display every digit in each display window in turn. Check all digits are clearly displayed without "ghosting".

Check that the correct decimal point lamp is lit as RANGE SWITCH [SF] is rotated.

Check that positive and negative polarity is indicated as appropriate.

Sample Check

Fig. 6.11 Ring Step Pulses

Set MODE SWITCH [SH] to MANUAL SAMPLE. Connect CD 1400 oscilloscope to board No. 19 terminal A6 and check that the waveform in fig. 6.11 is obtained when the SAMPLE button [SC] is pressed. Press the SAMPLE button [SC] about 10 times, checking that the ring only runs once each time. With the RANGE SWITCH [SF] set to 1 volt and with a display of approximately +1.00000 check that the readings do not vary by more than 3 digits.

Resolution

With MODE SWITCH [SH] on positions RESOLUTION 1, 2 and 5 check that the display moves in steps of 1, 2 and 5 digits respectively as the input is varied.

Variable Sample

Set MODE SWITCH [SH] to VAR. SAMPLE 0-5 with the VAR. SAMPLE POT [RV15] in the fully anti-clockwise [FAST] position. Short circuit the input leads. Connect oscilloscope to terminal A8 on board No. 19. Check that the ring runs every 20mS. Turn RV15 fully clockwise and check that the ring runs approximately every 5 secs $\pm$ 1 second.

Check that the ring runs approximately every 100msec when MODE SWITCH [SH] is set to 0-150 with RV15 fully anti-clockwise.

Turn RV15 fully clockwise and apply an input of approximately 1 volt to the LM1867. When the displayed reading changes from zero to 1 volt, commence timing and short circuit the input leads. When the reading changes from 1 volt to zero, check that 150 secs $\pm$ 50 secs has elapsed.

Maximum and Minimum Checks

Set MODE SWITCH [SH] to MAX, FILTER SWITCH [SG] to OUT and RANGE SWITCH [SF] to 1V. Check that the display follows a slowly increasing positive input but not a decreasing positive input.

Set MODE SWITCH [SH] to MIN and check that the display follows a slowly increasing negative input only.

Check that when the RESET BUTTON [SC] is pressed, the reading returns to zero if the input has been removed.

Counting

With RANGE SWITCH [SF] set to 10V, FILTER SWITCH [SG] to OUT and MODE SWITCH [SH] to RESOLUTION 1, obtain a displayed reading of +0.00997 and increase the input until +0.01013 is reached. Check that there are no jumps in the sequence and that all readings are steady.

Repeat the above with a negative input.

Repeat both the preceding paragraphs at the other transition points i.e. at 2 000, 4 000, 8 000, 10 000, 20 000, 40 000, 80 000 and 100 000 digits. There could be up to two miscounts on either polarity.

Repeat all the above checks for each polarity with RANGE SWITCH [SF] set to 1 volt.

All remaining checks of accuracy and linearity are made using specialised equipment in a controlled environment and must not be attempted [See Introduction].

CALIBRATION PROCEDURE

General

The LM1867 or LM1867C, and their internal references can be set against an external standard with a resolution of 0.001%.

For pratical measurement work the ultimate standard of voltage is the cadmium Weston cell.

The saturated cell has an e.m.f. of approximately 1.01860 volts, and the unsaturated cell has an e.m.f. of approximately 1.01930 volts. The voltmeter maximum reading, on the one volt range, is 1.01999, so that a calibration can be made against a standard cell to the nearest 10μV. The calibration point is then at very nearly full scale reading.

On the high voltage ranges, or, indeed, on the one volt range, other calibration sources may be used. However, it must be remembered that the absolute accuracy of the calibration is directly related to that of the standard which is employed. Hence, there would appear to be little point in calibrating LM1867 against an external standard unless its veracity exceeds that of the reference voltage which is built into the voltmeter.

In order to achieve the optimum accuracy the instrument should be set up against an external standard on the range to be used and at the ambient temperature at which the instrument will be employed. Errors which result from changes of range or temperature are covered in detail in Section 1.

Basic Principle

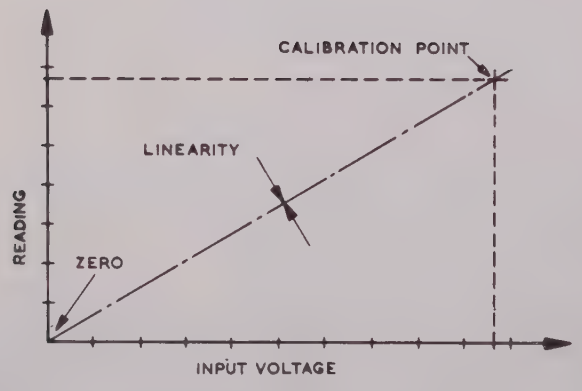


Fig. 6.12 Zero and Calibration Point Setting

Calibration against an external standard consists of setting zero and the calibration point [Fig. 6.12]. Provided that between these two points the instrument characteristic is linear, all inputs will give the correct reading. The linearity is set up, during extensive factory testing, by adjusting the ratios of the reference resistors. These controls are then sealed, and a user should not attempt to re-adjust them. Hence, calibration, on a given range, merely consists of shorting the input and setting zero, then, with the input connected to the standard, the slope of the characteristic is adjusted until the voltmeter reading is equal to the value of the standard. These adjustments are made using the calibration controls on the front panel.

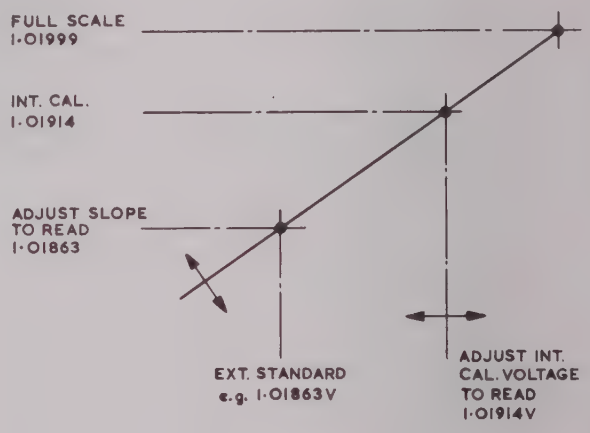


Fig. 6.13 Calibration of Internal Reference against an External Standard

If, during subsequent measurements, the voltmeter will be calibrated using its internal reference voltage, it is necessary to set this up. Therefore, following calibration against the external standard, an adjustment is made to bring the internal reference voltage onto the characteristic of Fig. 6.12. The process is illustrated by Fig. 6.13, which shows a detail of the full-scale end of the characteristic. The internal reference is derived from an unsaturated Weston cell, and this calibration technique compensates for the slight fall of e.m.f. which occurs with time. In practice the value of the internal reference is not itself altered, but an equivalent effect is obtained by an offset in the measuring circuits.

The reading for internal calibration is marked on the front panel alongside the controls.

Calibration Against External Standard

[1] With the voltmeter in the ambient temperature at which it is to be calibrated, switch on and allow it to settle for one hour. Plug in the input cable at the front panel and short circuit the end by pushing one plug into the other.

[2] Approximately one hour after switch on, set to the range which is to be calibrated. Switch to VARIABLE SAMPLE - FAST, INPUT LOW to MAINS EARTH and FILTER to 60dB.

[3] Adjust ZERO CAL POT so that the reading just flickers from +000000 to -000000.

[4] Check the zero for approximately 5 minutes to ensure that it is stable.

[5] Connect the input to the external standard and leave for two minutes to allow any thermals to settle.

[6] Switch to RESOLUTION 1 and adjust the +ve or the -ve CAL POT to bring the voltmeter reading to precisely the value of the standard. Rotate the control to just give +1 digit and -1 digit and leave it halfway between these two points.

[7] Reverse the input connections at the standard, allow thermals to settle and, using the other CAL. control, set the voltmeter reading as in [6].

Calibration of Internal Reference

The two controls for setting the internal reference are on a printed board underneath the chassis close to the front panel. Their location is shown in Fig. 6.14. RV2 gives coarse control of the overall adjustment, while RV1 is a fine setting. The total of the various contact and thermal potentials gives a net result which demands a fine correction in either a positive or a negative direction. This is not known for a particular voltmeter until it receives its final test, at which point the wires to pins 3 and 4 [Brown/Black and Orange/ Black] may have to be interchanged. The procedure differs slightly depending on these connections in your particular voltmeter.

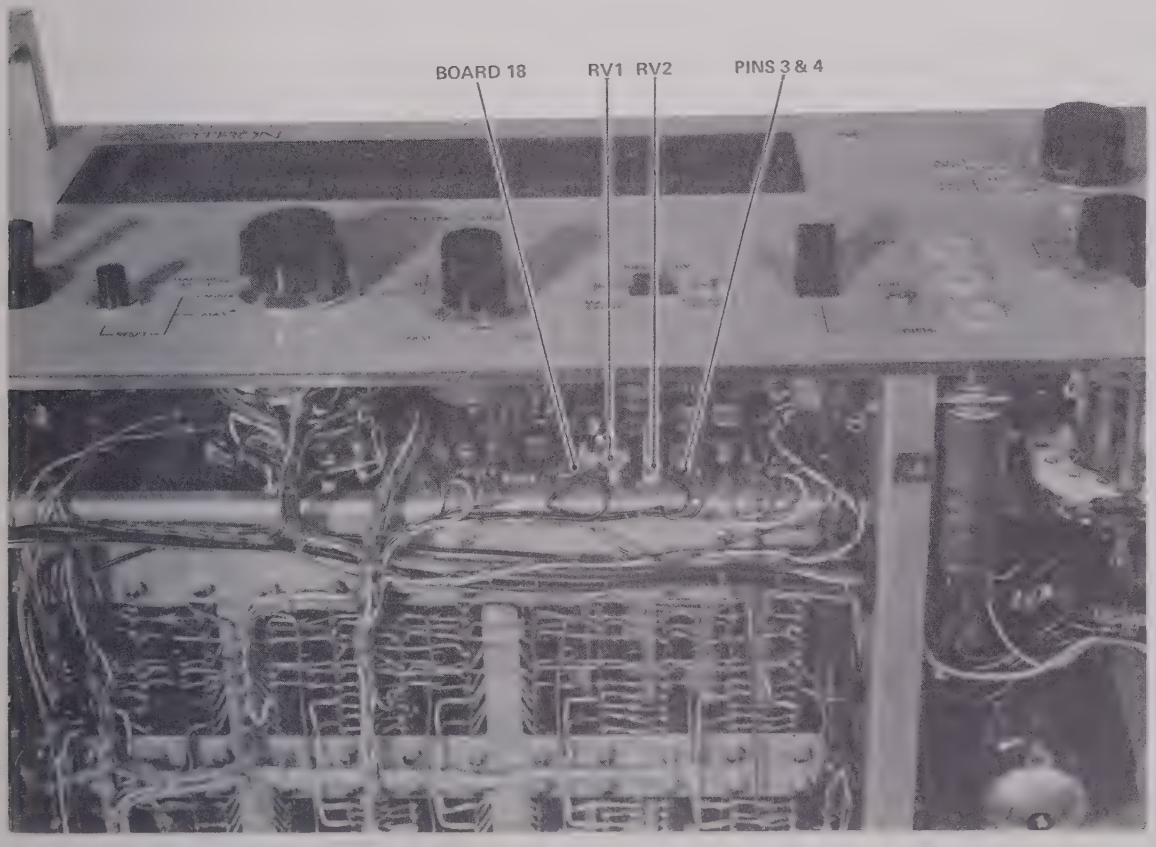


Fig. 6.14 Location of Calibration Adjustment Controls

When adjusting RV1 and RV2 the instrument must remain the right way up, otherwise the e.m.f. of the internal Weston cell may change.

[1] Calibrate against an external standard as described above.
[2] Withdraw the instrument from the case by about 3 inches and position it with the front panel over-hanging the edge of the bench, thus giving access to the reference adjustments RV1 and RV2.
[3] Set FILTER OUT, RANGE SWITCH to CAL and RESOLUTION to 1.

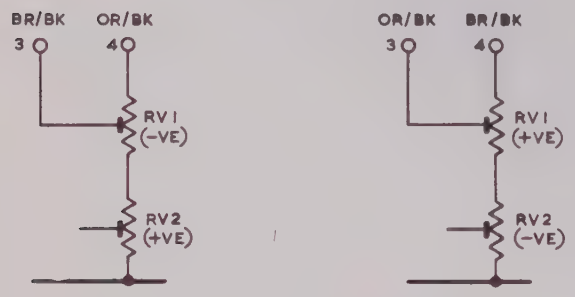


Fig. 6.15 Connection to Internal Reference Adjustment Controls

[4] Refer to Fig. 6.15 and the connections to pins 3 and 4 on board 18 to determine whether RV2 is to be adjusted at +ve or -ve.
[5] Throw the CAL. switch to the position determined in [4] and adjust RV2 so that the display shows the value given alongside the CAL, controls on the front panel. Turn RV2 so that the reading deviates by +1 digit and -1 digit and set it midway between these two points.
[6] Throw the CAL SWITCH to the opposite polarity position and adjust RV1 in a similar manner to obtain the identical reading.
[7] Check the reading with the CAL SWITCH at +ve and at -ve to ensure that in both positions the display shows the value given on the front panel.

SECTION 7

BINARY CODED DECIMAL FAN-OUT UNIT EX1869

GENERAL

This is an optional extra module which can be inserted into the space normally occupied by the blank chassis at the rear of the LM1867.

The information displayed by the LM1867 [i.e. range, polarity and measured voltage] is converted to B.C.D. and, together with the Print Command Pulse, is amplified by emitter followers identical to the one illustrated in Figure 7.1 to provide the outputs at socket SKF shown in Table 7.1. The remote sample facility is extended direct from the LM1867 to SKF.

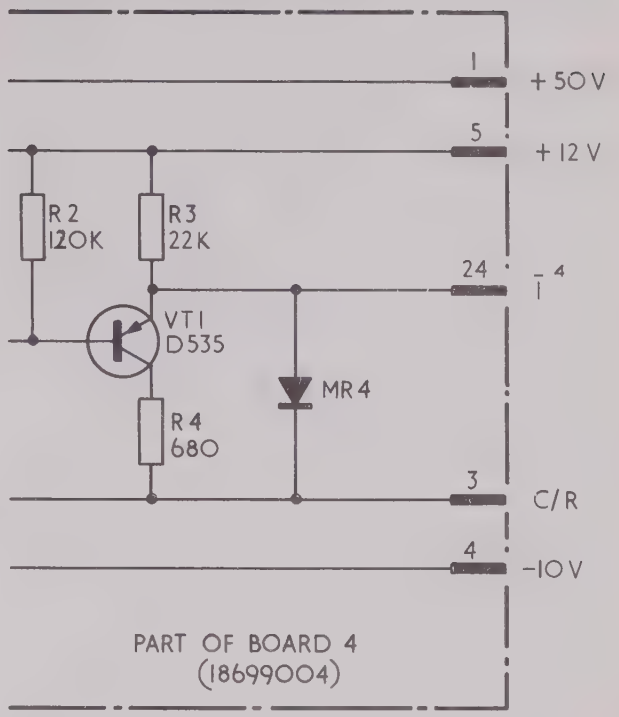


Fig. 7.1 EX 1869 Typical Emitter – Follower Output Stage

Table 7.1 EX 1869 Output Specification

Output	Nominal Voltage	Maximum Current available from pin 24	Maximum Current available into pin 24
Logical 0	0V	0.5mA	5.0mA
Logical 1	-6V	1.0mA	5.0mA

TECHNICAL DESCRIPTION

Outputs are taken from the LM1867 polarity bistable and the decimal point lamps and applied via emitter followers direct to EX1869 socket SKF. The quantity bistable outputs, however, are applied to logic circuits whose function is:-

[1] To convert the 10^4 output from 1224 code to BCD [1248 code].

[2] To provide carry functions which will update the 10^3, 10^4, and 1^5 stages when necessary.

10^0 and 10^1 Decade and Polarity (Board No.1)

This board contains ten identical emitter-followers which give a logical 1 output when an input is present.

10^3 Decade (Board No.3)

Referring to logic diagram 5, decimal point information is applied to terminals 17-20 and fed via EMITTER FOLLOWERS E6-E9 to terminals 21-24.

The $\overline{1}$ and $\overline{4}$ inputs on terminals 6 and 8 are amplified by EMITTER FOLLOWERS E2 and E4 respectively.

Providing that the $\overline{8}$ and $\overline{2}$ inputs are not energised together [i.e. for inputs less than $\overline{10}$], AND GATE &1 will remain closed since one of its inputs will always be a logical 0. &1 output will be a logical 0 which is inverted by INVERTER I1 and applied as a logical 1 to one input of AND GATES &2 and &3. A logical 1 occuring on either the $\overline{2}$ or $\overline{4}$ input lines will thus cause &2 or &3 to open and supply a logical 1 output to terminals 11 or 13 respectively. For inputs of less than 10, therefore, a BCD output will occur at terminals 10-13.

If a $\overline{10}$ is applied and the $\overline{8}$ and $\overline{2}$ lines are energised, &1 opens and &2 and &3 are inhibited by the logical 0 from I1. The output of each of the EMITTER FOLLOWERS E2 to E5 is logical 0. EMITTER FOLLOWER E1 output is logical 1 which is applied as a carry signal to the 10^3 decade on board No. 3.

If $\overline{11}$ is applied, the action is the same with the exception that the $\overline{1}$ output [terminal 10] is also energised [i.e. $\overline{1}$ is retained but $\overline{10}$ carried forward].

10^2 Decade and Range (Board No.2)

Reference should be made to the logic diagram 6.

$\overline{1}$ Input

OR GATE 01 opens applying logical 1 to one input of AND GATE &5. AND GATE &1 is closed and its logical 0 output is inverted by INVERTER I1 and applied as the second input to &5. &5 opens and feeds a logical 1 output to the $\overline{1}$ line.

OR GATE O2 is closed by its two logical 0 inputs. Logical 0 is applied by O2 to one input of AND GATE &6 which is thus inhibited.

Since both AND GATE &2 inputs are logical 0 its output, and hence OR GATE O4 input, is logical 0. O4 remains closed because both its inputs are logical 0 and AND GATE &7 is thereby inhibited.

AND GATE &3 is closed since it has two logical 0 inputs. One input of OR GATE O5 is thus logical 0. The $\overline{8}$ input line is logical 0 hence O5 is closed inhibiting AND GATE &8.

The $\overline{8}$ input also inhibits AND GATE &4 causing a logical 0 to be fed to the $\overline{C10}$ output via INVERTERS I4 and I5.

$\overline{2}$ Input

O1 is closed inhibiting &5.
The $\overline{2}$ line opens O2 to apply one logical 1 input to &6. &1 is closed and applies a logical 0 to &2 which also closes and supplies the second logical 1 input to &4 via INVERTER I2. &4 is inhibited by the logical 0 on the $\overline{8}$ input. Thus I4 applies the third logical 1 input to &6 which opens and energises the $\overline{2}$ output line.

Both the O4 inputs are logical 0 closing that gate and inhibiting &7.

&3 is closed by its two logical 0 inputs and applies a logical 0 input to O5. The second input to O5 is also logical 0 and the gate is closed inhibiting &8.

&4 is closed by the $\overline{8}$ input and a logical 0 is applied to the $\overline{C10}$ output via I4 and I5.

$\overline{4}$ Input

As before, the $\overline{1}$ output is a logical 0.
Since both O2 inputs are now logical 0 the gate closes to inhibit &6.
&2 is closed and applies logical 0 to one input of &3 which is inhibited. &3 output is inverted by INVERTER I3 and applied as a logical 1 to one input of &7.
O4 is opened by the $\overline{4}$ input and supplies the second logical 1 input to &7 which opens to energise the $\overline{4}$ output line.

O5 inputs are both logical 0 and the output inhibits &8. The $\overline{C10}$ output is a logical 0 as described before.

$\overline{8}$ Input

The $\overline{1}$ and $\overline{2}$ outputs remain at logical 0 as in the preceding description.

O4 now has two logical 0 inputs and closes to inhibit &7.

The $\overline{8}$ input opens O5 which supplies one logical 1 input to &8. O3 is closed since both its inputs are logical 0 and &4 is thus inhibited. $\overline{C10}$ is still held at logical 0 but a second logical 1 input is applied to &8 via I4. &8 opens to energise the $\overline{8}$ output line.

$\overline{C1}$ Input

O1 opens, applying logical 1 to one input of &5. &1 is closed and applies the second logical 1 input to &5 via I1. The $\overline{1}$ output line is thus energised.
The remaining outputs are inhibited as for a $\overline{1}$ input.

The $\overline{C10}$ output at pin 15 is fed to board No. 4 pin 6.

10^4 and 10^5 Decade (Board No.4)

The output from the quantity bistables on board No. 4 in the LM1867 is in 1224 code. The purpose of the LM1869 board No. 4 is to convert this to 1248 code and also to provide a 1^5 output when 100 000 reference bits have been selected.

Logic diagram 7 illustrates the operation of this board.

Other Outputs

Common Rail

Pins 23 and 24 on SKF are directly connected to the LM1867 common rail point.

Print Command

Pin 1 on SKF is supplied from the LM1867 print command circuit on board No. 19 [terminal A8.]. A negative-going, differentiated pulse greater than 7 volts occurs at this pin every time the LM1867 samples the input.

Inputs

External Sample

External sample may be commanded either by contact closure between pins 24 and 25 on socket SKF or by applying a 4 volt positive going step between common rail and socket SKF pin 25.

PHYSICAL DESCRIPTION

General

The EX1869 contains four plug-in printed circuit boards as listed in Table 7.2

Table 7.2 EX 1869 Printed Circuit Board Part Nos and Functions

Board Part No.	Position	Function
AD18699001	1	10^0 Decade emitter followers 10^1 Decade emitter followers Polarity emitter followers
AD18699002	2	10^2 Decade emitter followers and carry logic Range emitter followers
AD18699003	3	10^3 Decade emitter followers and carry logic
AD18699004	4	10^4 and 1^5 Decade emitter followers and carry logic

Dismantling Instructions

Removal of Fan-Out Unit

The unit is situated at the rear of the LM1867 chassis and can be removed without taking the voltmeter out of its case.

[1] Undo the two screws on the right and left edges of the EX1869 chassis.
[2] Withdraw the EX1869 from the LM1867 by a direct pull.

Removal of Boards

All boards are plug-in but are retained in position by two metal securing plates fitted at the top of the front and rear panels. The screws holding these plates should be loosened to allow them to be moved laterally. When the slots are aligned with the boards, they may be withdrawn by a direct upward pull.

Refitting of Boards

The reverse procedure to dismantling should be followed, care being taken to ensure the boards are inserted into the correct socket.

Servicing by Renewal of Printed Circuit Boards

A defective board may be replaced by a new board in all cases with no further setting-up procedure required.

TEST PROCEDURE

Recommended Test Equipment

Solartron LM1867 Digital Voltmeter
Multi-range meter [e.g. AVO meter Model 8]
Variable Voltage source up to 10 volts
Solartron CD1400 Oscilloscope
2.2KΩ ¼W 1% resistor

Detailed Tests

Binary Outputs — OFF Condition

Plug EX1869 FAN OUT UNIT into the LM1867 DIGITAL VOLTMETER. Switch on the LM1867 and select the 10V range with a resolution of 1 and the input lead short-circuited. Adjust the front panel ZERO CAL control to obtain a display of -00000. Switch to MANUAL SAMPLE to prevent the input from changing. Check with the AVO meter that the voltage on pins 30 to 50 [EX1869 socket SKF] inclusive is between +0.2 volts and +0.8 volts.

Binary Outputs Loaded — ON Condition

Connect a 2.2KΩ ¼W 1% resistor across the AVO meter terminals. Obtain in turn each reading in Table 7.3 and check that the voltage stated appears on the appropriate pins of SKF. [To obtain a particular reading, set the LM1867 to RESOLUTION 1 adjust the variable voltage source to bring up the reading on the display and then switch to MANUAL SAMPLE].

Table 7.3 EX 1869 Output Voltage Checks

Reading	-7.2 volts ±0.7 volts is present on Pin Nos			+0.2 to +0.8V is present on Pin No.	
00111	50	46	42		
00222	49	45	41		
00444	48	44	40		
00888	47	43	39		
01000	38			41	39
01040	38				
02000	37			38	
02040	37				
04000	36			37	
04040	36				
08000	35			36	
08040	35				
10000	34			37	35
10040	34				
20000	33			34	
20040	33				
40000	32			33	
40040	32				
80000	31			32	
80040	31			33	32
100000	30			33	31
100040	30			33	31

Polarity

Obtain any positive reading on the LM1867 and switch to manual. Check that the voltage on pin 3 is -7.2 volts ±0.7 volt and on pin 2 is +0.2 volts to +0.8 volts.

Obtain a negative reading and check that the voltage on pin 3 is +0.2 volts to +0.8 volts and on pin 2 is -7.2 volts ±0.7 volts.

Decimal Points

Set the LM1867 to the ranges indicated and check the voltages in Table 7.4.

Table 7.4 EX 1869 Polarity Checks

Range	Pins at -7.2V ±0.7V	Pins at +0.2 to +0.8V		
1V	26	27	28	29
10V	27	26		
100V	28			
1000V	29			

Mains Earth Continuity

Check that there is continuity between the Fan Out Unit socket SKF metalwork and the LM1867 frame.

Print Command

Set LM1867 to MANUAL SAMPLE. Press the MANUAL SAMPLE button checking with the oscilloscope that a negative-going differentiated pulse greater than 7 volts occurs on pin 1 every time it is pressed.

External Sample

Set LM1867 to 10V range. Check that the display changes to a new reading every time pins 24 and 25 on socket SKF are short-circuited. [Alter the input voltage each time before sampling.]

In a similar way, check that the LM1867 samples every time a positive-going step greater than 4 volts is applied to socket SKF pin 25. [An AVO meter on the Ohms range with one lead connected to Common Rail can be used to generate this step.]

Component Parts List Abbreviations

Circuit References		Component Composition	
R	Fixed Resistor [Ω]	A	Capacitor Polystyrene Tubular
RNL	Non Linear Resistor [Ω]	B	Capacitor Polyester Tubular Metalised
RV	Variable Resistor [Ω]	C	Capacitor Polyester Tubular Foil
C	Capacitor [μF]	D	Capacitor Paper Foil
MR	Diode	E	Capacitor Paper Metalised
L	Inductor	F	Capacitor Ceramic Tubular
V	Valve	G	Capacitor Ceramic Disc
VT	Transistor	H	Capacitor Silver Mica
IC	Integrated Circuit	J	Capacitor Electrolytic Al.
RL	Relay	K	Capacitor Electrolytic Al. Plain Foil
S	Switch	L	Capacitor Electrolytic Tantalum
PL	Plug	M	Capacitor Variable Air Preset
SK	Socket	N	Capacitor Variable Ceramic Disc Preset
MSP	Mains Selector Panel	P	Capacitor Variable Tubular Preset
T	Transformer	R	Capacitor Variable Mica Compression Preset
FS	Fuse	S	Capacitor Polyester Special
ILP	Lamp	T	Capacitor Polycarbon
B	Battery	V	Resistor Metalised Film
M	Meter	W	Resistor Composition <5%
TP	Terminal Post	X	Resistor Composition >5%
LK	Link	Y	Resistor Wire Wound
X	Other Components	Z	Resistor Oxide Film >5%

Units and Values			
A	Amp	G	Giga [10^9]
F	Farad	M	Mega [10^6]
H	Henry	k	kilo [10^3]
Ω	Ohm	m	milli [10^{-3}]
V	Volts	μ	micro [10^{-6}]
W	Watts	p	pico [10^{-12}]

Component Parts List for LM1867 Main Assembly

Cct. Ref.		General Description			Solartron Part No.
R1	W	75K	¼W	1%	170447500
R2	W	150K	¼W	1%	170451500
R3	W	150K	¼W	1%	170451500
R8	Z	1800	½W	5%	193531800
R9	V	4300	½W	1%	198334302
R10	Z	27K	½W	5%	193542700
R11	X	2700	½W	10%	172332700
R14	X	10	½W	10%	172311000
R17	Z	330	1W	5%	193423300
R18	X	100	½W	10%	172321000
R20	X	22K	½W	10%	172342200
R24	X	82K	½W	10%	172348200
R25	X	68K	½W	10%	172346800
R26	W	220K	¼W	5%	170552200
R30	W	2M	¼W	5%	170562000
R32	W	3.9M	¼W	5%	170563900
R33	W	3.9M	¼W	5%	170563900
R34	V	2.5M	¼W	0.5%	198562502
R35	Z	1500	1W	5%	193431500
R36	Pn	9M			
R37	Pn	900K	Matched Set		B14400166
R38	Pn	100K			
R39	V	100	½W	1%	198321004
R66	X	1M	¼W	10%	172361000
R67q	X	1M	¼W	10%	172361000
R86	Z	6800	½W	5%	193536800
R87	X	100K	½W	10%	172351000
R89	W	100K	¼W	5%	170551000
R90	X	68K	½W	10%	172346800

R91	V	220	½W	1%	198322202
R92	V	220	½W	1%	198322202
R113	X	12K	½W	10%	172341200
R115 to R118	X	22K	½W	10%	172342200
R120	X	68K	½W	10%	172346800
R121	X	82K	½W	10%	172348200
C1	B	0.47	400V	10%	220854700
C2	B	0.47	400V	10%	220854700
C3	J	1000	100V	-20% +50%	261491000
C4	J	4000	25V	-20% +50%	260894000
C5	J	5000	25V	-20% +50%	260895000
C6	J	50	150V	-20% +50%	261675000
C7	J	5000	50V	-20% +50%	261195000
C8	J	150	100V	-20% +50%	261581500
C9	J	500	25V	-20% +100%	260785000
C10	J	300	50V	-20% +100%	208600030
C11	J	250	50V	-20% +100%	271082500
C12	B	1.0	160V	10%	220361000
C13	L	50	18V	20%	208700041
C14	T	0.22	63V	20%	208200058
C15	B	1.0	160V	10%	220361000
C16	T	2.2	63V	20%	208200057
C20	B	0.47	160V	10%	220354700
C21	C	1000p	160V	10%	221331000
C22	S	.01	160V	1%	208200044
C23	B	.022	160V	1%	220042200
C24 to C26	B	.022	160V	1%	220042200
C27	B	0.33	160V	10%	220353300
C28	C	.022	160V	10%	221342200
C29	B	.22	160V	10%	220352200
C32	A	470pF	125V	10%	210224700
C66	D	0.047	630V	20%	208300059
C67	D	0.047	630V	20%	208300059

MR1 to MR4	ISO21	300521700
MR5 to MR8	ISO20	300520670
MR9	40AS	300520520
MR10	60AS	300520540
MR11	SD3 Solartron	300522160
MR16 to MR19	SD1 Solartron	300520070
VT1	OC36	300550180
VT2	OC35	300550170
VT3	OC35	300550170
VT4	2N3055	300552340

RV1	Y	1000	1W	5%	121931000
RV2	Y	1000	1W	5%	121931000
RV4	Y	250	1W	5%	110150250
RV5	Y	250	1W	5%	110150250
RV6	X	50K	¼W	20%	110007230
RV15	X	5M	1W	10%	110024040

RLA	C1414/Z 6.3V	B14400119
RLB	C1414/Z 6.3V	B14400119
SB	Slider SPDT	375000040
SC	PBSPCO	378000030
SD	Key Lever	378200220
SE	Toggle DP On/Off	376000300
SF	Wafer	B18670030
SG	Wafer	B14400115
SH	Wafer	371308020
SK	Toggle 3P DT	376000560
SKA	Connector 50 way	352550030
SKB	Connector 242/B/2	352802010
SKC	Connector Socket Fixed	352103010
SKD	Connector Fixed 242/B/2	352802010
SKE	Connector Socket Black	352501090
SKF	Connector Socket Blue	352501130
SKG	Connector Socket Red	352501080
MSP1	Mains Selector Panel	399000050
T1	Mains Transformer	B14400168
FS1	Fuse Slo-Blo 750MA	360105070
ILP1 to ILP4	Indicator Neon 16L	300720140
ILP7	Indicator Neon L1166	300720300
ILP8	Indicator Neon L1166	300720300
ILP9	Indicator Neon 23L	300720240
BY1	Standard Cell D-845-D/1	310010070

Component Parts List for Printed Circuit Board No.1

Cct Ref.	General	Description			Solartron Part No.
R2	X	56K	½W	10%	172345600
R3	Z	16K	½W	5%	193541600
R5	Z	1800	1W	5%	193431800
R8	Z	3300	½W	5%	193533300
R9	Z	1800	1W	5%	193431800

R12	Z	56K	½W	5%	193545600	R45	Z	1800	½W	5%	193531800
R13	Z	3300	½W	5%	193533300						
R14	X	68K	½W	10%	172346800	RV1	X	5600	¼W	20%	110012330
R16	X	82K	½W	10%	172348200	RV2	X	2700	¼W	20%	110012270
R17	X	6800	½W	10%	172336800						
R18	Z	10K	½W	5%	193541000	C1	C	4700p	160V	10%	221334700
R19	X	68K	½W	10%	172346800	C2	C	2200p	400V	10%	222332200
R21	X	2200	½W	10%	172332200	C3	C	.015	160V	10%	221341500
R22	X	10K	½W	10%	172341000	C4	J	100	35V	-20%	
R24	Z	15K	½W	5%	193541500					+50%	208600127
R25	Z	33K	½W	5%	193543300	MR1					
R26	Z	8200	½W	5%	193538200	to		S.D.1	Solartron		300520070
R27	Z	22K	½W	5%	193542200	MR7					
R28	Z	30K	½W	5%	193543000	MR8		S.D.3	Solartron		300522160
R29	Z	68K	½W	5%	193546800	MR9					
R30	X	33K	½W	10%	172343300	to		S.D.1	Solartron		300520070
R31	X	47K	½W	10%	172344700	MR11					
R32	X	2200	½W	10%	172332200	MR12		S.D.3	Solartron		300522160
R33	X	10K	½W	10%	172341000	MR13		S.D.3	Solartron		300522160
R34	X	6800	½W	10%	172336800	MR14		IN3497			300522800
R35	Z	10K	½W	5%	193541000						
R36	Z	10K	½W	5%	193541000	VT1		2N4007			300553350
R37	Z	22K	½W	5%	193542200	VT2		2N4007			300553350
R38	Z	47K	½W	5%	193544700	VT5		BFY50			300553610
R39	X	15K	½W	10%	172341500	VT6		BCY70			300553590
R40	V	5600	½W	1%	198635604	VT7		ACY20			300550680
R41	Y	150	2.6W	10%	173521500	VT10		ACY20			300550680
R42	X	2200	½W	10%	172332200	VT12		ACY20			300550680
R43	V	2200	½W	1%	198332204	VT13		ACY20			300550680
R44	V	390	½W	1%	198323901	VT11		2N1302			300550450

Component Parts List for Printed Circuit Board No.2

Cct Ref.	General		Description		Solartron Parts No.						
R1	X	100K	½W	10%	172351000	R23	X	22K	½W	10%	172342200
R2	X	47K	½W	10%	172344700	R24	X	22K	½W	10%	172342200
R3	X	22K	½W	10%	172342200	R25	X	10K	½W	10%	172341000
R4	X	220K	½W	10%	172352200	R26	X	10K	½W	10%	172341000
R5	X	1800	½W	10%	172331800	R27	X	3300	½W	10%	172333300
R6	X	27K	½W	10%	172342700	R28	X	10K	½W	10%	172341000
R7	X	10K	½W	10%	172341000	R29	X	22K	½W	10%	172342200
R8	X	22K	½W	10%	172342200	R30	X	22K	½W	10%	172342200
R9	X	2700	½W	10%	172332700	R31	X	3300	½W	10%	172333300
R10	X	1500	½W	10%	172331500	R32	X	330K	½W	10%	172353300
R11	X	27K	½W	10%	172342700	R33	X	5600	½W	10%	172335600
R12	X	1800	½W	10%	172331800	R34	X	56K	½W	10%	172345600
R13	X	120K	½W	10%	172351200	R35	X	56K	½W	10%	172345600
R14	X	47K	½W	10%	172344700	R36	X	5600	½W	10%	172335600
R15	X	100K	½W	10%	172351000	R37	X	330K	½W	10%	172353300
R16	X	1500	½W	10%	172331500	R38	Z	68K	½W	5%	193546800
R17	Z	12K	½W	5%	193541200	R39	Z	27K	½W	5%	193542700
R18	Z	3900	½W	5%	193533900	R40	X	33K	½W	10%	172343300
R19	Z	3600	1W	5%	193433600	R41	X	15K	½W	10%	172341500
R20	X	3900	½W	10%	172333900	R42	X	6800	½W	10%	172336800
R21	X	3900	½W	10%	172333900	R43	Z	62K	½W	5%	193546200
R22	X	10K	½W	10%	172341000	R44	X	220K	½W	10%	172352200
						R45	X	6800	½W	10%	172336800

C1	C	4700p	160V	10%	221334700	VT1	BCY71		300553570
C2	C	470p	160V	10%	221324700	VT2	ACY20		300550680
C3	C	.022	160V	10%	221342200	VT3	BCY70		300553590
C4	C	.022	160V	10%	221342200	VT4	BCY70		300553590
C5	C	2200p	400V	10%	222332200	VT5	ACY20		300550680
C6	C	.01	160V	10%	221341000	VT6	BCY71		300553570
C7	C	2200p	400V	10%	222332200	VT7	ACY18		300550540
C8	C	220p	400V	10%	222322200	VT8	2N1302		300550450
C9	C	220p	400V	10%	222322200	VT9	ACY18		300550540
						VT10			
MR1						to	ACY20		300550680
to	S.D.1		Solartron		300520070	VT13			
MR12						VT14	2N1305		300550910
						VT15	ACY20		300550680
						VT16	ACY20		300550680

Component Parts List for Printed Circuit Board No.3

Cct. Ref.	General	Description			Solartron Part No.
R1	X	47K	½W	10%	172344700
R2	X	47K	½W	10%	172344700
R3	Z	3300	½W	5%	193533300
R4	X	22K	½W	10%	172342200
R5	X	22K	½W	10%	172342200
R6	X	3300	½W	10%	172333300
R7	X	3300	½W	10%	172333300
R8	X	39K	¼W	10%	172043900
R10					
to	X	39K	¼W	10%	172043900
R19					
R21					
to	X	39K	¼W	10%	172043900
R29					
R30	Z	24K	½W	5%	193542400
R31	Z	15K	½W	5%	193541500
R32	Z	15K	½W	5%	193541500
R33	Z	6800	½W	10%	172336800
R34	Z	15K	½W	5%	193541500
R35	Z	15K	½W	5%	193541500
R36	X	6800	½W	10%	172336800
R37	Z	15K	½W	5%	193541500
R38	Z	15K	½W	5%	193541500
R39	X	6800	½W	10%	172336800
R40	Z	15K	½W	5%	193541500
R41	Z	15K	½W	5%	193541500
R42	X	6800	½W	10%	172336800
R43	X	47K	½W	10%	172344700
R44	X	47K	½W	10%	172344700
R45					
to	X	120K	½W	10%	172351200
R54					

MR1			
to	S.D.1	Solartron	300520070
MR3			
MR4	S.D.3	Solartron	300522160
MR5			
to	S.D.1	Solartron	300520070
MR8			
MR10			
to	S.D.1	Solartron	300520070
MR22			
MR25			
to	S.D.1	Solartron	300520070
MR29			
MR31			
to	S.D.1	Solartron	300520070
MR33			
MR35			
to	S.D.1	Solartron	300520070
MR47			
MR49			
to	S.D.1	Solartron	300520070
MR54			
MR56			
to	S.D.1	Solartron	300520070
MR63			

VT1	A1778/2	300551430
VT2	2N1304	300550880
VT3		
to	A1778/2	300551430
VT14		
VT15		
to	R2033	300553670
VT22		
V1	ZM1022	300011340

Component Parts List for Printed Circuit Board No.4

Cct Ref		General	Description		Solartron Part No.
R1	X	15K	½W	10%	172341500
R4	X	22K	½W	10%	172342200
R5	X	220K	½W	10%	172352200
R6	X	1800	½W	10%	172331800
R7	X	27K	½W	10%	172342700
R8	X	2700	½W	10%	172332700
R9	Z	1800	1W	5%	193431800
R10	Z	1800	1W	5%	193431800
R11	X	22K	½W	10%	172342200
R12	X	120K	½W	10%	172351200
R13	X	10K	½W	10%	172341000
R14	X	1500	½W	10%	172331500
R15	X	27K	½W	10%	172342700
R16	X	1800	½W	10%	172331800
R17	X	220K	½W	10%	172352200
R18	X	22K	½W	10%	172342200
R19	Z	1800	1W	5%	193431800
R20	Z	1800	1W	5%	193431800
R22	X	2700	½W	10%	172332700
R23	X	1500	½W	10%	172331500
R24	X	10K	½W	10%	172341000
R25	X	22K	½W	10%	172342200
R26	X	120K	½W	10%	172351200
R27	X	1800	½W	10%	172331800
R28	X	27K	½W	10%	172342700
R29	X	220K	½W	10%	172352200
R30	X	22K	½W	10%	172342200
R31	Z	1800	1W	5%	193431800
R32	Z	1800	1W	5%	193431800
R34	X	2700	½W	10%	172332700
R35	X	1500	½W	10%	172331500
R36	X	10K	½W	10%	172341000
R37	X	120K	½W	10%	172351200
R38	X	22K	½W	10%	172342200
R39	Z	1800	1W	5%	193431800
R40	X	22K	½W	10%	172342200
R41	X	220K	½W	10%	172352200
R42	X	1800	½W	10%	172331800
R43	X	27K	½W	10%	172342700
R44	X	1500	½W	10%	172331500
R45	X	2700	½W	10%	172332700
R46	X	10K	½W	10%	172341000
R47	X	120K	½W	10%	172351200
R48	Z	1800	1W	5%	193431800
R49	X	22K	½W	10%	172342200
R51	X	33K	½W	10%	172343300
C1	C	4700p	160V	10%	221334700
C2	G	470p	500V	-20% +80%	241024701
C3	C	.022	160V	10%	221342200
C4	C	4700p	160V	10%	221334700
C5	G	470p	500V	-20% +80%	241024701
C6	C	.022	160V	10%	221342200
C7	G	470p	500V	-20% +80%	241024701
C8	C	4700p	160V	10%	221334700
C9	C	.022	160V	10%	221342200
C10	C	4700p	160V	10%	221334700
C11	G	470p	500V	-20% +80%	241024701
C12	C	.022	160V	10%	221342200

MR3	S.D.3	Solartron	300522160
MR4 to MR7	S.D.1	Solartron	300520070
MR9	S.D.3	Solartron	300522160
MR10	S.D.3	Solartron	300522160
MR13	S.D.1	Solartron	300520070
MR14	S.D.3	Solartron	300522160
MR15	S.D.1	Solartron	300520070
MR16	S.D.1	Solartron	300520070
MR17	SZD15	Solartron	300521390
MR21	S.D.1	Solartron	300520070
MR22	S.D.1	Solartron	300520070
VT1	ACY18		300550540
VT2	ACY18		300550540
VT3	ACY20		300550680
VT4	ACY18		300550540
VT5	ACY18		300550540
VT6	ACY20		300550680
VT7	ACY18		300550540
VT8	ACY18		300550540
VT9	ACY20		300550680
VT10	ACY18		300550540
VT11	ACY18		300550540
VT12	ACY20		300550680
VT13	ACY18		300550540

Component Parts List for Printed Circuit Board No.5

Cct. Ref.		General	Description		Solartron Part No.
R1	X	47K	½W	10%	172344700
R2	X	47K	½W	10%	172344700
R3	Z	3300	½W	5%	193533300
R4	X	22K	½W	10%	172342200
R5	X	22K	½W	10%	172342200
R6	X	3300	½W	10%	172333300
R7	X	3300	½W	10%	172333300
R8	X	39K	¼W	10%	172043900
R9	X	39K	¼W	10%	172043900
R10 to R29	X	39K	¼W	10%	172043900

R30	Z	24K	½W	5%	193542400	MR1			
R31	Z	15K	½W	5%	193541500	to	S.D.1	Solartron	300520070
R32	Z	15K	½W	5%	193541500	MR3			
R33	X	6800	½W	10%	172336800	MR4	S.D.3	Solartron	300522160
R34	Z	15K	½W	5%	193541500	MR5			
R35	Z	15K	½W	5%	193541500	to	S.D.1	Solartron	300520070
R36	X	6800	½W	10%	172336800	MR54			
R37	Z	15K	½W	5%	193541500	MR56			
R38	Z	15K	½W	5%	193541500	to	S.D.1	Solartron	300520070
R39	X	6800	½W	10%	172336800	MR61			
R40	Z	15K	½W	5%	193541500				
R41	Z	15K	½W	5%	193541500				
R42	X	6800	½W	10%	172336800				
R43	X	47K	½W	10%	172344700	VT1	A1778/2		300551430
R44	X	47K	½W	10%	172344700	VT2	2N1304		300550880
R45						VT3			
to	X	120K	½W	10%	172351200	to	A1778/2		300551430
R54						VT14			

Component Parts List for Printed Circuit Board No.6

Cct. Ref.	General Description				Solartron Part No.
R1	X	15K	½W	10%	172341500
R3	X	33K	½W	10%	172343300
R4	X	22K	½W	10%	172342200
R5	X	220K	½W	10%	172352200
R6	X	1800	½W	10%	172331800
R7	X	27K	½W	10%	172342700
R8	X	2700	½W	10%	172332700
R9	Z	1800	1W	5%	193431800
R10	Z	1800	1W	5%	193431800
R11	X	22K	½W	10%	172342200
R12	X	120K	½W	10%	172351200
R13	X	10K	½W	10%	172341000
R14	X	1500	½W	10%	172331500
R15	X	27K	½W	10%	172342700
R16	X	1800	½W	10%	172331800
R17	X	220K	½W	10%	172352200
R18	X	22K	½W	10%	172342200
R19	Z	1800	1W	5%	193431800
R20	Z	1800	1W	5%	193431800
R21	X	15K	½W	10%	172341500
R22	X	2700	½W	10%	172332700
R23	X	1500	½W	10%	172331500
R24	X	10K	½W	10%	172341000
R25	X	22K	½W	10%	172342200
R26	X	120K	½W	10%	172351200
R27	X	1800	½W	10%	172331800
R28	X	27K	½W	10%	172342700
R29	X	220K	½W	10%	172352200
R30	X	22K	½W	10%	172342200
R31	Z	1800	1W	5%	193431800
R32	Z	1800	1W	5%	193431800
R34	X	2700	½W	10%	172332700
R35	X	1500	½W	10%	172331500
R36	X	10K	½W	10%	172341000
R37	X	120K	½W	10%	172351200
R38	X	22K	½W	10%	172342200
R39	Z	1800	1W	5%	193431800
R40	X	22K	½W	10%	172342200
R41	X	220K	½W	10%	172352200
R42	X	1800	½W	10%	172331800
R43	X	27K	½W	10%	172342700
R44	X	1500	½W	10%	172331500
R45	X	2700	½W	10%	172332700
R46	X	10K	½W	10%	172341000
R47	X	120K	½W	10%	172351200
R48	Z	1800	1W	5%	193431800
R49	X	22K	½W	10%	172342200
C1	C	4700p	160V	10%	221334700
C2	G	470p	500V	-20%	
				+80%	241024701
C3	C	.022	160V	10%	221342200
C4	C	4700p	160V	10%	221334700
C5	G	470p	500V	-20%	
				+80%	241024701
C6	C	.022	160V	10%	221342200
C7	G	470p	500V	-20%	
				+80%	241024701
C8	C	4700p	160V	10%	221334700
C9	C	.022	160V	10%	221342200
C10	C	4700p	160V	10%	221334700
C11	G	470p	500V	-20%	
				+80%	241024701
C12	C	.022	160V	10%	221342200
VT15					
to	R2033				300553670
VT22					
V1	ZM1022				300011340

MR1	S.D.1	Solartron	300520070
MR2	S.D.1	Solartron	300520070
MR3	S.D.3	Solartron	300522160
MR4 to MR8	S.D.1	Solartron	300520070
MR9	S.D.3	Solartron	300522160
MR10	S.D.3	Solartron	300522160
MR11	S.D.1	Solartron	300520070
MR12	S.D.1	Solartron	300520070
MR14	S.D.3	Solartron	300522160
MR15	S.D.1	Solartron	300520070
MR16	S.D.1	Solartron	300520070
MR17	SZD15	Solartron	300521390

VT1	ACY18		300550540
VT2	ACY18		300550540
VT3	ACY20		300550680
VT4	ACY18		300550540
VT5	ACY18		300550540
VT6	ACY20		300550680
VT7	ACY18		300550540
VT8	ACY18		300550540
VT9	ACY20		300550680
VT10	ACY18		300550540
VT11	ACY18		300550540
VT12	ACY20		300550680
VT13	ACY18		300550540

Component Parts List
for
Printed Circuit Boards No.7, 9, 11

Cct Ref		General	Description		Solartron Part No.
R1	Z	24K	½W	5%	193542400
R2	X	1000	½W	10%	172331000
R3	Z	15K	½W	5%	193541500
R4	Z	15K	½W	5%	193541500
R5	X	3300	½W	10%	172333300
R6	X	3300	½W	10%	172333300
R7	X	1000	½W	10%	172331000
R8	X	56K	½W	10%	172345600
R9	X	56K	½W	10%	172345600
R10	X	6800	½W	10%	172336800
R11	Z	15K	½W	5%	193541500
R12	X	120K	½W	10%	172351200
R13	X	4700	½W	10%	172334700
R14	X	47K	½W	10%	172344700
R15	Z	15K	½W	5%	193541500
R16	X	6800	½W	10%	172336800
R17	X	39K	½W	10%	172343900
R18	X	120K	½W	10%	172351200
R19	X	47K	½W	10%	172344700
R20	Z	15K	½W	5%	193541500
R21	Z	15K	½W	5%	193541500
R22	X	39K	½W	10%	172343900
R23	X	4700	½W	10%	172334700
R24	X	120K	½W	10%	172351200
R25	X	39K	½W	10%	172343900
R26	X	6800	½W	10%	172336800
R27	Z	15K	½W	5%	193541500
R28	X	39K	½W	10%	172343900
R29	X	4700	½W	10%	172334700
R30	X	120K	½W	10%	172351200
R31	X	120K	½W	10%	172351200
R32	X	39K	½W	10%	172343900
R33	Z	15K	½W	5%	193541500
R34	X	6800	½W	10%	172336800
R35	X	120K	½W	10%	172351200

R36	X	120K	½W	10%	172351200
R37	X	4700	½W	10%	172334700
R38	X	39K	½W	10%	172343900
R39	X	39K	½W	10%	172343900
R40	X	120K	½W	10%	172351200
R41	X	120K	½W	10%	172351200
R42	X	4700	½W	10%	172334700
R43	X	39K	½W	10%	172343900
R44	X	120K	½W	10%	172351200
R45	X	39K	½W	10%	172343900
R46	X	39K	½W	10%	172343900

MR1 to MR20	S.D.1	Solartron	300520070
VT1 to VT4	R2033		300553670
VT5	A1778/2		300551430
VT6	R2033		300553670
VT7	R2033		300553670
VT8	A1778/2		300551430
VT9	A1778/2		300551430
VT10	R2033		300553670
VT11	R2033		300553670
VT12	A1778/2		300551430
VT13	A1778/2		300551430
VT14	R2033		300553670
VT15	R2033		300553670
VT16 to VT21	A1778/2		300551430
V1	ZM1022		300011340

Component Parts List for Printed Circuit Board No.8

Cct. Ref.		General	Description		Solartron Parts No.
R1	X	15K	½W	10%	172341500
R3	X	33K	½W	10%	172343300
R4	X	22K	½W	10%	172342200
R5	X	220K	½W	10%	172352200
R6	X	1800	½W	10%	172331800
R7	X	27K	½W	10%	172342700
R8	X	2700	½W	10%	172332700
R9	Z	1800	1W	5%	193431800
R10	Z	1800	1W	5%	193431800
R11	X	22K	½W	10%	172342200
R12	X	120K	½W	10%	172351200
R13	X	10K	½W	10%	172341000
R14	X	1500	½W	10%	172331500
R15	X	27K	½W	10%	172342700
R16	X	1800	½W	10%	172331800
R17	X	220K	½W	10%	172352200
R18	X	22K	½W	10%	172342200
R19	Z	1800	1W	5%	193431800
R20	Z	1800	1W	5%	193431800
R21	X	15K	½W	10%	172341500
R22	X	2700	½W	10%	172332700
R23	X	1500	½W	10%	172331500
R24	X	10K	½W	10%	172341000
R25	X	22K	½W	10%	172342200
R26	X	120K	½W	10%	172351200
R27	X	1800	½W	10%	172331800
R28	X	27K	½W	10%	172342700
R29	X	220K	½W	10%	172352200
R30	X	22K	½W	10%	172342200
R31	Z	1800	1W	5%	193431800
R32	Z	1800	1W	5%	193431800
R34	X	2700	½W	10%	172332700
R35	X	1500	½W	10%	172331500
R36	X	10K	½W	10%	172341000
R37	X	120K	½W	10%	172351200
R38	X	22K	½W	10%	172342200
R39	Z	1800	1W	5%	193431800
R40	X	22K	½W	10%	172342200
R41	X	220K	½W	10%	172352200
R42	X	1800	½W	10%	172331800
R43	X	27K	½W	10%	172342700
R44	X	1500	½W	10%	172331500
R45	X	2700	½W	10%	172332700
R46	X	10K	½W	10%	172341000
R47	X	120K	½W	10%	172351200
R48	Z	1800	1W	5%	193431800
R49	X	22K	½W	10%	172342200
R50	X	22K	½W	10%	172342200
C1	C	4700p	160V	10%	221334700
C2	G	470p	500V	-20% +80%	241024701
C3	C	.022	160V	10%	221342200
C4	C	4700p	160V	10%	221334700
C5	G	470p	500V	-20% +80%	241024701
C6	C	.022	160V	10%	221342200
C7	G	470p	500V	-20% +80%	241024701
C8	C	4700p	160V	10%	221334700
C9	C	.022	160V	10%	221342200
C10	C	4700p	160V	10%	221334700
C11	G	470p	500V	-20% +80%	241024701
C12	C	.022	160V	10%	221342200

MR1	S.D.1	Solartron	300520070
MR2	S.D.1	Solartron	300520070
MR3	S.D.3	Solartron	300522160
MR4 to MR8	S.D.1	Solartron	300520070
MR9	S.D.3	Solartron	300522160
MR10	S.D.3	Solartron	300522160
MR11	S.D.1	Solartron	300520070
MR12	S.D.1	Solartron	300520070
MR14	S.D.3	Solartron	300522160
MR15	S.D.1	Solartron	300520070
MR16	S.D.1	Solartron	300520070
MR17	SZD15	Solartron	300521390
MR18	S.D.1	Solartron	300520070
MR19	SZD6.2	Solartron	300521240
MR20	S.D.1	Solartron	300520070

VT1	ACY18	300550540
VT2	ACY18	300550540
VT3	ACY20	300550680
VT4	ACY18	300550540
VT5	ACY18	300550540
VT6	ACY20	300550680
VT7	ACY18	300550540
VT8	ACY18	300550540
VT9	ACY20	300550680
VT10	ACY18	300550540
VT11	ACY18	300550540
VT12	ACY20	300550680
VT13	ACY18	300550540

Component Parts List for Printed Circuit Board No.10

Cct. Ref.		General	Description		Solartron Part No.
R1	X	15K	½W	10%	172341500
R3	X	33K	½W	10%	172343300
R4	X	22K	½W	10%	172342200
R5	X	220K	½W	10%	172352200
R6	X	1800	½W	10%	172331800
R7	X	27K	½W	10%	172342700
R8	X	2700	½W	10%	172332700
R9	Z	1800	1W	5%	193431800

R10	Z	1800	1W	5%	193431800
R11	X	22K	½W	10%	172342200
R12	X	120K	½W	10%	172351200
R13	X	10K	½W	10%	172341000
R14	X	1500	½W	10%	172331500
R15	X	27K	½W	10%	172342700
R16	X	1800	½W	10%	172331800
R17	X	220K	½W	10%	172352200
R18	X	22K	½W	10%	172342200
R19	Z	1800	1W	5%	193431800
R20	Z	1800	1W	5%	193431800
R21	X	15K	½W	10%	172341500
R22	X	2700	½W	10%	172332700
R23	X	1500	½W	10%	172331500
R24	X	10K	½W	10%	172341000
R25	X	22K	½W	10%	172342200
R26	X	120K	½W	10%	172351200
R27	X	1800	½W	10%	172331800
R28	X	27K	½W	10%	172342700
R29	X	220K	½W	10%	172352200
R30	X	22K	½W	10%	172342200
R31	Z	1800	1W	5%	193431800
R32	Z	1800	1W	5%	193431800
R33	X	15K	½W	10%	172341500
R34	X	2700	½W	10%	172332700
R35	X	1500	½W	10%	172331500
R36	X	10K	½W	10%	172341000
R37	X	120K	½W	10%	172351200
R38	X	22K	½W	10%	172342200
R39	Z	1800	1W	5%	193431800
R40	X	22K	½W	10%	172342200
R41	X	220K	½W	10%	172352200
R42	X	1800	½W	10%	172331800
R43	X	27K	½W	10%	172342700
R44	X	1500	½W	10%	172331500
R45	X	2700	½W	10%	172332700
R46	X	10K	½W	10%	172341000
R47	X	120K	½W	10%	172351200
R48	Z	1800	1W	5%	193431800
R49	X	22K	½W	10%	172342200

C1	C	4700p	160V	10%	221334700
C2	G	470p	500V	-20%	
				+80%	241024701
C3	C	.022	160V	10%	221342200
C4	C	4700p	160V	10%	221334700
C5	G	470p	500V	-20%	
				+80%	241024701
C6	C	.022	160V	10%	221342200
C7	G	470p	500V	-20%	
				+80%	241024701
C8	C	4700p	160V	10%	221334700
C9	C	.022	160V	10%	221342200
C10	C	4700p	160V	10%	221334700
C11	G	470p	500V	-20%	
				+80%	241024701
C12	C	.022	160V	10%	221342200

MR1	S.D.1	Solartron	300520070
MR2	S.D.1	Solartron	300520070
MR3	S.D.3	Solartron	300522160
MR4 to MR8	S.D.1	Solartron	300520070
MR9	S.D.3	Solartron	300522160
MR10	S.D.3	Solartron	300522160
MR11	S.D.1	Solartron	300520070
MR12	S.D.1	Solartron	300520070
MR13	S.D.1	Solartron	300520070
MR14	S.D.3	Solartron	300522160
MR15	S.D.1	Solartron	300520070
MR16	S.D.1	Solartron	300520070
MR17	SZD15	Solartron	300521390

VT1	ACY18
VT2	ACY18
VT3	ACY20
VT4	ACY18
VT5	ACY18
VT6	ACY20
VT7	ACY18
VT8	ACY18
VT9	ACY20
VT10	ACY18
VT11	ACY18
VT12	ACY20
VT13	ACY18

Component Parts List for Printed Circuit Board No.12

Cct. Ref.	General Description			Solartron Part No.
R1	X	15K	½W	10%	172341500
R3	X	33K	½W	10%	172343300
R4	X	22K	½W	10%	172342200
R5	X	220K	½W	10%	172352200
R6	X	1800	½W	10%	172331800
R7	X	27K	½W	10%	172342700
R8	X	2700	½W	10%	172332700
R9	Z	1800	1W	5%	193431800
R10	Z	1800	1W	5%	193431800
R11	X	22K	½W	10%	172342200
R12	X	120K	½W	10%	172351200
R13	X	10K	½W	10%	172341000
R14	X	1500	½W	10%	172331500
R15	X	27K	½W	10%	172342700
R16	X	1800	½W	10%	172331800
R17	X	220K	½W	10%	172352200
R18	X	22K	½W	10%	172342200
R19	Z	1800	1W	5%	193431800

R20	Z	1800	1W	5%	193431800	C6	C	.022	160V	10%	221342200
R21	X	15K	½W	10%	172341500	C7	G	470p	500V	-20%	
R22	X	2700	½W	10%	172332700					+80%	241024701
R23	X	1500	½W	10%	172331500	C8	C	4700p	160V	10%	221334700
R24	X	10K	½W	10%	172341000	C9	C	.022	160V	10%	221342200
R25	X	22K	½W	10%	172342200	C10	C	4700p	160V	10%	221334700
R26	X	120K	½W	10%	172351200	C11	G	470p	500V	-20%	
R27	X	1800	½W	10%	172331800					+80%	241024701
R28	X	27K	½W	10%	172342700	C12	C	.022	160V	10%	221342200
R29	X	220K	½W	10%	172352200						
R30	X	22K	½W	10%	172342200	MR1		S.D.1	Solartron		300520070
R31	Z	1800	1W	5%	193431800	MR2		S.D.1	Solartron		300520070
R32	Z	1800	1W	5%	193431800	MR3		S.D.3	Solartron		300522160
R33	X	15K	½W	10%	172341500	MR4					
R34	X	2700	½W	10%	172332700	to		S.D.1	Solartron		300520070
R35	X	1500	½W	10%	172331500	MR8					
R36	X	10K	½W	10%	172341000	MR9		S.D.3	Solartron		300522160
R37	X	120K	½W	10%	172351200	MR10		S.D.3	Solartron		300522160
R38	X	22K	½W	10%	172342200	MR11					
R39	Z	1800	1W	5%	193431800	to		S.D.1	Solartron		300520070
R40	X	22K	½W	10%	172342200	MR13					
R41	X	220K	½W	10%	172352200	MR14		S.D.3	Solartron		300522160
R42	X	1800	½W	10%	172331800	MR15		S.D.1	Solartron		300520070
R43	X	27K	½W	10%	172342700	MR16		S.D.1	Solartron		300520070
R44	X	1500	½W	10%	172331500	MR17		SZD15	Solartron		300521390
R45	X	2700	½W	10%	172332700						
R46	X	10K	½W	10%	172341000	VT1		ACY18			300550540
R47	X	120K	½W	10%	172351200	VT2		ACY18			300550540
R48	Z	1800	1W	5%	193431800	VT3		ACY20			300550680
						VT4		ACY18			300550540
						VT5		ACY18			300550540
						VT6		ACY20			300550680
C1	C	4700p	160V	10%	221334700	VT7		ACY18			300550540
C2	G	470p	500V	-20%		VT8		ACY18			300550540
				+80%	241024701	VT9		ACY20			300550680
C3	C	.022	160V	10%	221342200	VT10		ACY18			300550540
C4	C	4700p	160V	10%	221334700	VT11		ACY18			300550540
C5	G	470p	500V	-20%		VT12		ACY20			300550680
				+80%	241024701	VT13		ACY18			300550540

Component Parts List for Printed Circuit Board No.13

Cct. Ref.	General	Description		Solartron Part No.					
R1	X	100	½W	10%	172321000	R15	Z	2700	½W	5%	193532700
R2	X	100	½W	10%	172321000	R16	Z	2700	½W	5%	193532700
R4	X	4700	½W	10%	172334700	R17	Z	24K	½W	5%	193542400
R5	Z	1000	1W	5%	193431000	R18	V	11K	½W	1%	198641104
R6	Z	330	½W	5%	193523300	R19	V	2200	½W	1%	198332204
R7	X	470	½W	10%	172324700	R21	X	4700	½W	10%	172334700
R8	V	1000	½W	1%	198331004	R22	Z	620	1W	5%	193426200
R9	V	3400	½W	1%	160400365	R23	X	8200	½W	10%	172338200
R10	Z	10K	½W	5%	193541000	R24	X	22K	½W	10%	172342200
R11	Z	20K	½W	5%	193542000						
R12	V	33K	½W	1%	198343304	RV1	Y	100	1W	5%	121921000
R13	V	11K	½W	1%	198341104						
R14	Z	5100	1W	5%	193435100	C1	B	0.1	160V	10%	220351000
						C2	F	100p	750V	10%	240421000
						C3	L	22	15V	20%	208700015

MR1	SVM105		300524280
MR2	S.D.3	Solartron	300522160
MR3	SZD13	Solartron	300523920
MR4	S.D.3	Solartron	300522160
MR5	SZD18	Solartron	300521300
MR6	SZD3	Solartron	300523880

VT1	BCY70	300553590
VT2	BCY70	300553590
VT3	BFY50	300553610
VT4 to VT9	BCY70	300553590
VT10	2N2484	300552860
VT11	2N2484	300552860

Component Parts List for Printed Circuit Board No.14

Cct. Ref.	General	Description		Solartron Part No.
R1	X 22K	½W	10%	172342200
R2	Z 3300	½W	5%	193533300
R3	X 47K	½W	10%	172344700
R4	Z 27K	½W	1%	195442700
R5 to R7	Z 47K	½W	1%	195444700
R8	X 3300	½W	10%	172333300
R9	X 220	½W	10%	172322200
R10	X 22M	½W	10%	172372200
R11	Z 15K	½W	1%	195441500
R12	Z 12K	½W	1%	195441200
R13	Z 15K	½W	1%	195441500
R14	X 27K	½W	10%	172342700
R15	X 3300	½W	10%	172333300
R16	X 2200	½W	10%	172332200
R17	X 2200	½W	10%	172332200
R18	X 100K	½W	10%	172351000
R19	Z 15K	½W	1%	195441500
R20	Z 18K	½W	1%	195441800
R21	X 2200	½W	10%	172332200
R22	Z 15K	½W	1%	195441500
R23	X 10K	½W	10%	172341000
R24	X 22K	½W	10%	172342200
R25	X 33	½W	10%	172313300
R26	X 2200	½W	10%	172332200
R27	X 2200	½W	10%	172332200
R28	Z 12K	½W	1%	195441200
R29	X 68	½W	10%	172316800
R30	X 47K	½W	10%	172344700
R31	X 47K	½W	10%	172344700
R32	X 22M	½W	10%	172372200
R33	X 1M	½W	10%	172361000
R34	Z 2700	½W	1%	195432700
R35	Z 2000	½W	1%	195432000
RV1	X 100K	0.1W	20%	137351000
C1	J 25	50V	-20% +100%	261072500
C2	S 470p	160V	10%	221324700
C3	B 1.0	160V	10%	220361000
C4	S 470p	160V	10%	221324700
C5	A 100p	400V	10%	222321000
C6	A 100p	400V	10%	222321000
C7	J 25	50V	-20% +100%	261072500
C8	F 1000p	500V	20%	208400048
C9	A 100p	400V	10%	222321000
MR1 to MR6	S.D.3	Solartron		300522160

VT1	SL205	300552800
VT2	2N4007	300553350
VT3	BCY71	300553570
VT4	BCY71	300553570
VT5	2N1303	300551970
VT6	BCY70	300553590
VT7	BCY70	300553590
VT8	2N1303	300551970
VT9	BCY70	300553590
VT10	BFY50	300553610
VT11	BCY71	300553570
VT12	BCY71	300553570
VT13	2N2484	300552860

Component Parts List for Printed Circuit Board No.15

Cct Ref.	General Description			Solartron Part No.
R1	Z 2200	½W	1%	195432200
R2	Z 82K	½W	1%	195448200
R3	Z 82K	½W	1%	195448200
R4	Z 68K	½W	1%	195446800
R5	X 6800	½W	10%	172336800
R6	X 3300	½W	10%	172333300
R7	Z 10K	½W	1%	195441000
C1	J 25	50V	-20% +100%	261072500

C2	J	50	25V	-20% +100%	260775000	VT1	2N2484			300552860
						V1	ME1400			300005300
MR1 to MR3	S.D.3		Solartron		300522160	V2	ME1400			300005300

Component Parts List for Printed Circuit Board No.16

Cct. Ref	General Description				Solartron Part No.					
R1	X	47K	½W	10%	172344700	R27	Z	2000	½W	1%	195432000
R2	X	5600	½W	10%	172335600	R28	Z	6800	½W	1%	195436800
R3	X	47K	½W	10%	172344700	R29	Z	2700	½W	1%	195432700
R4	X	330	½W	10%	172323300	R30	Z	4700	½W	1%	195434700
R5	X	8200	½W	10%	172338200						
R6	Z	27K	½W	1%	195442700	RV1	Y	1000	½W	10%	121131000
R7	X	330	½W	10%	172323300	C1	C	.01	160V	10%	221341000
R8	Z	10K	½W	1%	195441000	C3	F	56p	750V	10%	240415600
R9	X	330	½W	10%	172323300	C4	F	56p	750V	10%	240415600
R10	Z	27K	½W	1%	195442700	C5	F	22p	750V	10%	240412200
R11	X	12K	½W	10%	172341200	C6	F	22p	750V	10%	240412200
R12	X	1000	½W	10%	172331000	C7	F	27p	750V	10%	240412700
R13	X	1000	½W	10%	172331000						
R14	Z	15K	½W	1%	195441500	MR1					
R15	Z	6800	½W	1%	195436800	to	S.D.3		Solartron		300522160
R16	Z	15K	½W	1%	195441500	MR4					
R17	W	1M	¼W	5%	170561000						
R18	W	1M	¼W	5%	170561000						
R19	Z	470	½W	5%	193524700	VT1					
R20	Z	15K	½W	1%	195441500	to	BCY71				300553570
R21	Z	18K	½W	1%	195441800	VT4					
R22	Z	15K	½W	1%	195441500	VT5					
R23	Z	470	½W	5%	193524700	to	BCY70				300553590
R24	X	12K	½W	10%	172341200	VT8					
R25	X	5600	½W	10%	172335600	VT9	BCY71				300553570
R26	X	5600	½W	10%	172335600	VT10	BCY71				300553570

Component Parts List for Printed Circuit Board No.17

Cct. Ref	General Description		Solartron Part No.						
R1	Y	224.65K	Matched	R12	Y	3.9	½W	1%	198303903
R2	Y	400K	Set	R13	Y	19.3K			Matched
R3	Y	200K	B14400165	R14	Y	19.3K			Set
R4	Y	100K	Set 'B'	R15	Y	31.52K			B14400167
R5	Y	50K		R16	Y	25K			Matched
R6	Y	215.75K		R17	Y	50K			Set
R7	Y	400K	Matched	R18	Y	100K			B14400140
R8	Y	200K	Set	R19	Y	200K			
R9	Y	100K	B14400165	R20	Y	250K			
R10	Y	200K	Set 'A'	R21	V	500K	½W	0.25%	160400368
R11	Y	4.166K		R22	V	1M	½W	0.25%	160400393
				R23	V	2M	½W	0.5%	198562002
				R24	V	2.5M	½W	0.5%	198562502

R25	V	5M	½W	1%	160400367	RV4	Y	100	1W	5%	121921000
R26	W	10M	½W	1%	170771000	RV5	Y	500	½W	5%	121925000
R27	W	20M	¾W	2%	160000234	RV6	Y	200	½W	5%	121922000
R28	V	5M	½W	1%	160400367	RV7	Y	100	1W	5%	121921000
R29	V	500K	½W	0.25%	160400368	RV8	Y	200	½W	5%	121922000
R30	V	2.5M	½W	0.5%	198562502	RV9	Y	1000	1W	5%	121931000
R31	W	10M	½W	1%	170771000	RV10	Y	2000	1W	5%	121932000
R32	W	10M	½W	1%	170771000	RV11					
R33	V	5M	½W	1%	160400367	to	X	1M	0.1W	20%	137361000
R34	W	10M	½W	1%	170771000	RV14					
						C1	A	22p	125V	10%	210212200
RV1	Y	1000	½W	5%	121931000	MR1					
RV2	Y	500	½W	5%	121925000	to		S.D.3	Solartron		300522160
RV3	Y	200	½W	5%	121922000	MR8					

Component Parts List for Printed Circuit Board No.18

Cct Ref.	General Description				Solartron Part No.	R23	X	3300	½W	5%	193533300
						R24	X	47K	½W	10%	172344700
R1	X	220K	½W	10%	172352200						
R2	X	47K	½W	10%	172344700	C1	F	1500p	500V	10%	208400087
R3	X	47K	½W	10%	172344700	C2	F	1500p	500V	10%	208400087
R4	X	47K	½W	10%	172344700						
R5	X	10K	½W	10%	172341000	RV1	X	2200	0.1W	20%	137332200
R6	X	33K	½W	10%	172343300	RV2	Y	20K	½W	10%	121242000
R7	X	4700	½W	10%	172334700						
R8	X	100K	½W	10%	172351000	MR1		S.D.1	Solartron		300520070
R9	X	10K	½W	10%	172341000	MR2		S.D.3	Solartron		300522160
R10	X	100K	½W	10%	172351000	MR3		S.D.3	Solartron		300522160
R11	X	220K	½W	10%	172352200	MR4					
R12	X	220K	½W	10%	172352200	to		S.D.1	Solartron		300520070
R13	X	100K	½W	10%	172351000	MR17					
R14	X	33K	½W	10%	172343300	VT1		2N3440			300552790
R15	X	33K	½W	10%	172343300	VT2		A1778/2			300551430
R16	X	4700	½W	10%	172334700	VT3		BCY70			300553590
R17	X	4700	½W	10%	172334700	VT4		BC107/S			300553320
R18	X	47K	½W	10%	172344700	VT5		SL205			300552800
R19	X	10K	½W	10%	172341000	VT6		2N1303			300551970
R20	X	220K	½W	10%	172352200	VT7		2N1303			300551970
R21	X	220K	½W	10%	172352200	VT8		BCY70			300553590
R22	X	47K	½W	10%	172344700	VT9		BCY70			300553590

Component Parts List for Printed Circuit Board No.19

Cct Ref.	General Description				Solartron Part No.	R6	X	4700	½W	10%	172334700
						R7	X	33K	½W	10%	172343300
R1	X	1500	½W	10%	172331500	R8	Z	22K	½W	5%	193542200
R2	Z	680	½W	5%	193526800	R9	X	56K	½W	10%	172345600
R3	X	1800	½W	10%	172331800	R10	X	3900	½W	10%	172333900
R4	X	150K	½W	10%	172351500	R11	X	15K	½W	10%	172341500
R5	X	47K	½W	10%	172344700	R12	X	150K	½W	10%	172351500

R13	X	6800	½W	10%	172336800
R14	Z	47K	½W	5%	193544700
R15	X	6800	½W	10%	172336800
R16	X	100K	½W	10%	172351000
R17	X	100K	½W	10%	172351000
R18	X	150K	½W	10%	172351500
R19	X	47K	½W	10%	172344700
R20	X	68K	½W	10%	172346800
R21	X	220	½W	10%	172322200
R22	X	10K	½W	10%	172341000
R23	X	1000	½W	10%	172331000
R24	X	3900	½W	10%	172333900
R25	X	47K	½W	10%	172344700
R26	X	47K	½W	10%	172344700
R27	X	27K	½W	10%	172342700
R28	Z	6200	½W	5%	192536200
R29	X	4700	½W	10%	172334700
R30	X	150K	½W	10%	172351500
R31	X	3900	½W	10%	172333900
R32	X	47K	½W	10%	172344700
R33	X	10K	½W	10%	172341000
R34	X	47K	½W	10%	172344700
R36	X	100	½W	10%	172321000
R37	X	4700	½W	10%	172334700
R38	X	1500	½W	10%	172331500
R39	X	12K	½W	10%	172341200
R40	X	4700	½W	10%	172334700
R41	X	100	½W	10%	172321000
R42	X	47K	½W	10%	172344700
R43 to R49	Not Fitted				
R50	X	1M	¼W	10%	172361000
C1	C	.022	160V	10%	221342200
C2	G	1000p	500V	-20% +80%	241031001
C3	C	.022	160V	10%	221342200
C4	C	.01	160V	10%	221341000
C5	S	.01	160V	1%	208200044
C6	C	1000p	160V	10%	221331000
C7	C	.01	160V	1%	221341000
C9	B	0.1	160V	10%	220351000
C10	C	0.1	160V	10%	221341000
MR1	S.D.1		Solartron		300520070
MR2	S.D.1		Solartron		300520070
MR3	S.D.1		Solartron		300520070
MR4	S.D.1		Solartron		300520070
MR6	S.D.1		Solartron		300520070
MR7	S.D.1		Solartron		300520070
VT1 to VT9	ACY20				300550680
VT10	2N1305				300550910
VT11	2N1302				300550450
VT12	BCY70				300553590
VT13	2N1302				300550450
VT14	2S302				300550630

Component Parts List
for
EX1869 Main Assembly

Cct. Ref.	General Description		Solartron Part No.
PLA	Conn. Plug Fxd 50 Way	1	352350020
SKF	Conn. Skt. Fxd 50 Way	1	352550020

Component Parts List
for
Printed Circuit Board No.1

Cct. Ref.		General Description			Solartron Part No.
R1 to R4	X	22K	½W	10%	172342200
R5 to R8	X	56K	½W	10%	172345600
R9 to R12	X	680	½W	10%	172326800
R13 to R16	X	22K	½W	10%	172342200
R17 to R20	X	56K	½W	10%	172345600

R21 to R24	X	680	½W	10%	172326800
R25	X	22K	½W	10%	172342200
R26	X	56K	½W	10%	172345600
R27	X	680	½W	10%	172326800
R28	X	22K	½W	10%	172342200
R29	X	56K	½W	10%	172345600
R30	X	680	½W	10%	172326800
MR1 to MR10	SD1		Solartron		300520070
VT1 to VT10	D535				300551620

Component Parts List
for
Printed Circuit Board No.2

Cct. Ref.		General Description			Solartron Part No.
R1 to R4	X	22K	½W	10%	172342200
R5 to R8	X	56K	½W	10%	172345600
R9 to R12	X	680	½W	10%	172326800
R13	X	22K	½W	10%	172342200
R14	Z	100K	½W	5%	193551000
R15	Z	100K	½W	5%	193551000
R16	X	680	½W	10%	172326800
R17	X	22K	½W	10%	172342200
R18	Z	100K	½W	5%	193551000
R19	Z	100K	½W	5%	193551000
R20	X	680	½W	10%	172326800
R21	X	22K	½W	10%	172342200
R22	Z	100K	½W	5%	193551000
R23	Z	100K	½W	5%	193551000
R24	X	680	½W	10%	172326800
R25	X	22K	½W	10%	172342200

R26	Z	100K	½W	5%	193551000
R27	Z	100K	½W	5%	193551000
R28	X	680	½W	10%	172326800
R29	X	4.7K	½W	10%	172334700
R30	X	56K	½W	10%	172345600
R31	X	6.8K	½W	10%	172336800
R32	X	39K	½W	10%	172343900
R33	X	22K	½W	10%	172342200
MR1	SD1		Solartron		300520070
MR2	SD3		Solartron		300522160
MR3	SD1		Solartron		300520070
MR4	SD1		Solartron		300520070
MR5	SD3		Solartron		300522160
MR6 to MR12	SD1		Solartron		300520070
VT1 to VT8	D535				300551620
VT9	A1778/2				300551430
VT10	A1778/2				300551430

Component Parts List for Printed Circuit Board No.3

Cct. Ref.	General	Description		Solartron Part No.
R1	X	39K	½W 10%	172343900
R2	X	120K	½W 10%	172351200
R3	X	22K	½W 10%	172342200
R4	X	680	½W 10%	172326800
R5	X	56K	½W 10%	172345600
R6	X	22K	½W 10%	172342200
R7	X	39K	½W 10%	172343900
R8	X	4.7K	½W 10%	172334700
R9	X	22K	½W 10%	172342200
R10	X	39K	½W 10%	172343900
R11	X	120K	½W 10%	172351200
R12	X	22K	½W 10%	172342200
R13	X	680	½W 10%	172326800
R14	X	56K	½W 10%	172345600
R15	X	22K	½W 10%	172342200
R16	X	39K	½W 10%	172343900
R17	X	22K	½W 10%	172342200
R18	X	4.7K	½W 10%	172334700
R19	X	39K	½W 10%	172343900
R20	X	120K	½W 10%	172351200
R21	X	22K	½W 10%	172342200
R22	X	680	½W 10%	172326800
R23	X	56K	½W 10%	172345600
R24	X	22K	½W 10%	172342200
R25	X	39K	½W 10%	172343900
R26	X	22K	½W 10%	172342200
R27	X	4.7K	½W 10%	172334700
R28	X	39K	½W 10%	172343900
R29	X	120K	½W 10%	172351200
R30	X	22K	½W 10%	172342200
R31	X	680	½W 10%	172326800
R32	X	47K	½W 10%	172344700
R33	X	10K	½W 10%	172341000
R34	X	220K	½W 10%	172352200
R35	X	15K	½W 10%	172341500
R36	X	47K	½W 10%	172344700
R37	X	220K	½W 10%	172352200
R38	X	22K	½W 10%	172342200
MR1	SD1		Solartron	300520070
MR2	SD1		Solartron	300520070
MR3	SD3		Solartron	300522160
MR4 to MR8	SD1		Solartron	300520070
MR9	SD3		Solartron	300522160
MR10	SD3		Solartron	300522160
MR11 to MR15	SD1		Solartron	300520070
MR16	SD3		Solartron	300522160
MR17 to MR21	SD1		Solartron	300520070
MR22	SD3		Solartron	300522160
MR23 to MR26	SD1		Solartron	300520070
VT1	D535			300551620
VT2	A1778/2			300551430
VT3	A1778/2			300551430
VT4	D535			300551620
VT5	A1778/2			300551430
VT6	A1778/2			300551430
VT7	D535			300551620
VT8	A1778/2			300551430
VT9	A1778/2			300551430
VT10	D535			300551620
VT11	BCY 70			300553590
VT12	BCY 70			300553590

Component Parts List for Printed Circuit Board No.4

Cct. Ref.	General	Description		Solartron Part No.
R1	X	39K	½W 10%	172343900
R2	X	120K	½W 10%	172351200
R3	X	22K	½W 10%	172342200
R4	X	680	½W 10%	172326800
R5	X	56K	½W 10%	172345600
R6	X	22K	½W 10%	172342200
R7	X	39K	½W 10%	172343900
R8	X	22K	½W 10%	172342200
R9	X	4.7K	½W 10%	172334700
R10	X	39K	½W 10%	172343900
R11	X	120K	½W 10%	172351200
R12	X	22K	½W 10%	172342200
R13	X	680	½W 10%	172326800
R14	X	56K	½W 10%	172345600
R15	X	22K	½W 10%	172342200
R16	X	220K	½W 10%	172352200
R17	X	2.2M	½W 10%	172362200
R18	X	33K	½W 10%	172343300
R19	X	39K	½W 10%	172343900
R20	X	120K	½W 10%	172351200
R21	X	22K	½W 10%	172342200
R22	X	680	½W 10%	172326800
R23	X	56K	½W 10%	172345600
R24	X	22K	½W 10%	172342200
R25	X	220K	½W 10%	172352200
R26	X	2.2M	½W 10%	172362200

R27	X	33K	½W	10%	172343300
R28	X	39K	½W	10%	172343900
R29	X	120K	½W	10%	172351200
R30	X	22K	½W	10%	172342200
R31	X	680	½W	10%	172326800
R32	X	39K	½W	10%	172343900
R33	X	100K	½W	10%	172351000
R34	X	4.7K	½W	10%	172334700
R35	X	22K	½W	10%	172342200
R36	X	27K	½W	10%	172342700
R37	X	22K	½W	10%	172342200
R38	X	680	½W	10%	172326800

MR1	SD1	Solartron	300520070
MR2	SD1	Solartron	300520070
MR3	SD3	Solartron	300522160
MR4 to MR8	SD1	Solartron	300520070
MR9	SD3	Solartron	300522160
MR10 to MR12	SD1	Solartron	300520070
MR13	SD3	Solartron	300522160
MR14	SD3	Solartron	300522160
MR15	SD1	Solartron	300522170
MR16	SD1	Solartron	300522170
MR17	SD3	Solartron	300522160
MR18 to MR20	SD1	Solartron	300520070
MR21	SD3	Solartron	300522160
MR22	SD3	Solartron	300522160
MR23	SD1	Solartron	300520070
MR24	SD1	Solartron	300520070
MR25	SD3	Solartron	300522160
MR26 to MR29	SD1	Solartron	300520070

VT1	D535		300551620
VT2	A1778/2		300551430
VT3	A1778/2		300551430
VT4	D535		300551620
VT5	A1778/2		300551430
VT6	BCY70		300553590
VT7	D535		300551620
VT8	A1778/2		300551430
VT9	BCY70		300553590
VT10	D535		300551620
VT11	A1778/2		300551430
VT12	D535		300551620

Component Parts List for EX1626 Printed Circuit Board No.1

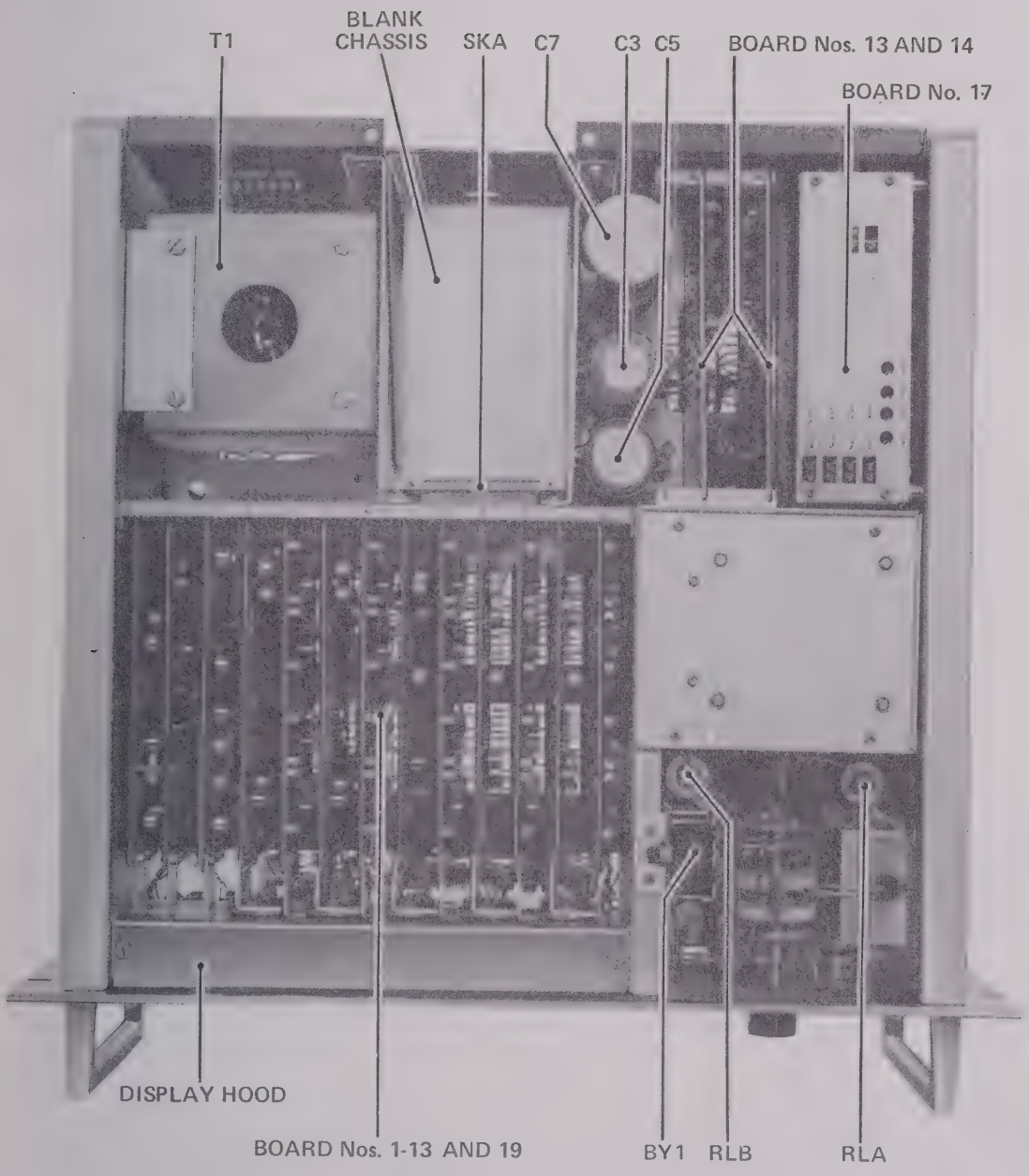
Cct. Ref.	General Description				Solartron Part No.
R1	V	100K	1.2W	0.1%	160400375
R2	V	100K	1.2W	0.1%	160400375
R3	V	10.865K	0.4W	0.05%	160400374
SK C	Conn. Socket 4mm Red				352501080
SK D	Conn. Socket 4mm Blue				352501130
PL A	Conn. Plug 4mm				351301340
PL B	Conn. Plug 4mm				351301340
RV1	Y	500	½W	20%	110031290
RV2	Y	500	½W	20%	110031290

Component Parts List for EX1627 Printed Circuit Board No.1

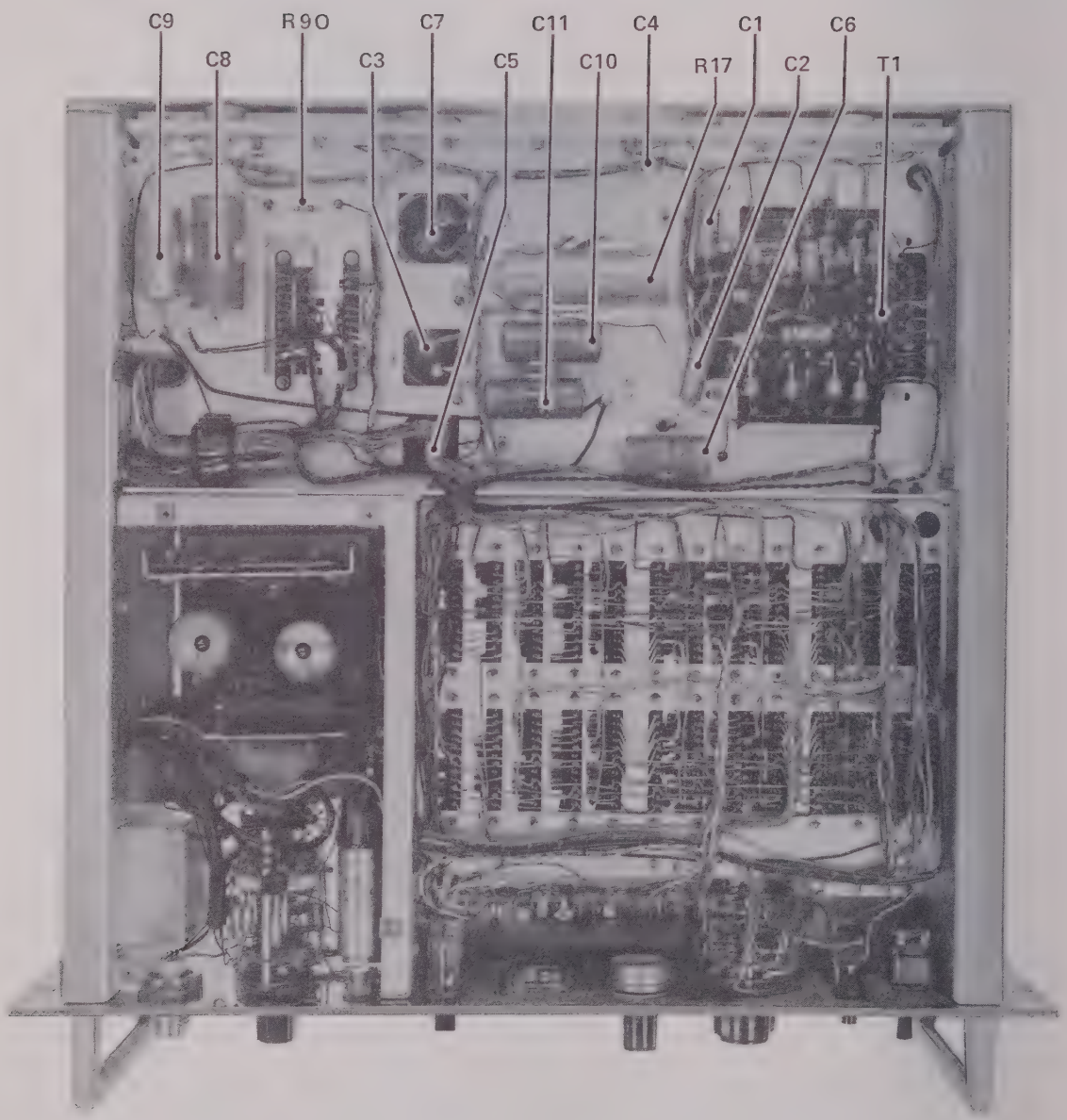
Cct. Ref.	General Description				Solartron Part No.
R1	V	25K	0.4W	0.05%	160400373
R2	V	25K	0.4W	0.05%	160400373
R3	V	31.74K	0.8W	0.05%	160400372
SK C	Conn. Socket 4mm Red				352501080
SK D	Conn. Socket 4mm Blue				352501130
PLA	Conn. Plug 4mm				351301340
PLB	Conn. Plug 4mm				351301340
RV1	Y	100	½W	20%	110031180
RV2	Y	100	½W	20%	110031180

Component Parts List
for
EXI628 Printed Circuit Board No.1

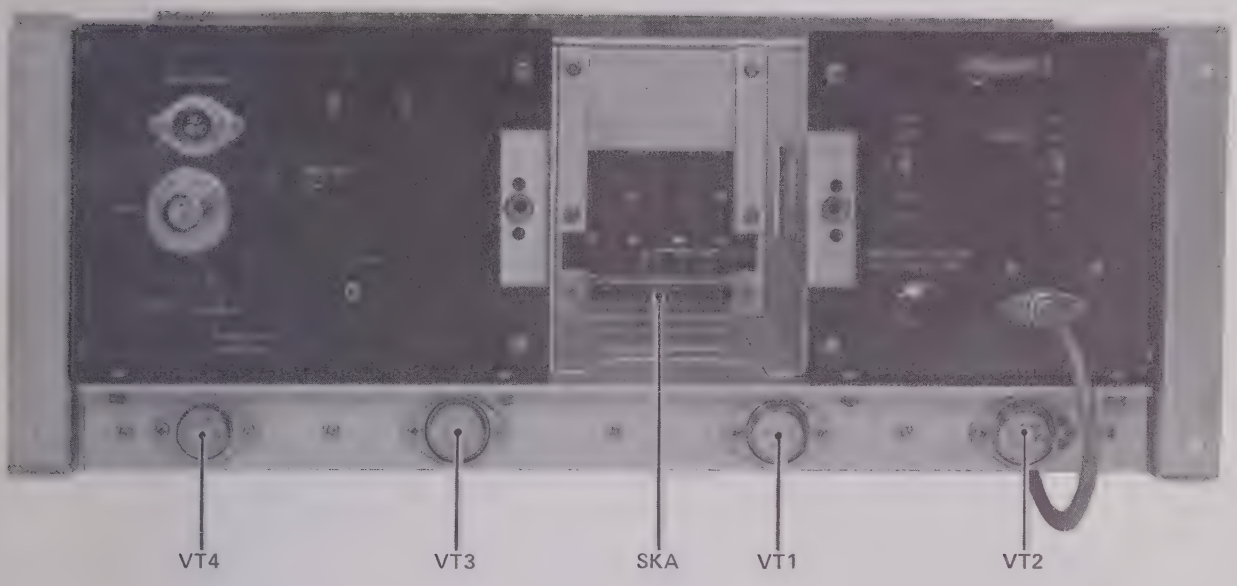
Cct. Ref.					Solartron Part No.			
						SK C	Conn. Socket 4mm Red	352501080
						SK D	Conn. Socket 4mm Blue	352501030
R1	V	10.44K	0.4W	0.05%	160400371	PLA	Conn. Plug 4mm	351301340
R2	V	10.44K	0.4W	0.05%	160400371	PLB	Conn. Plug 4mm	351301340



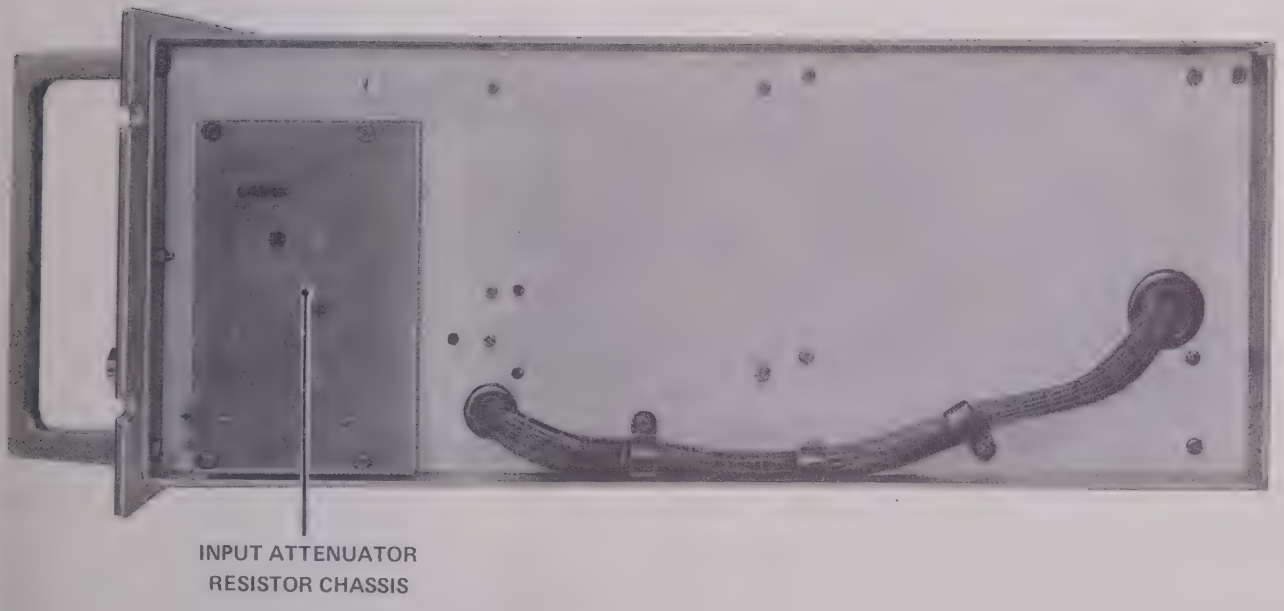
LM1867 Top View



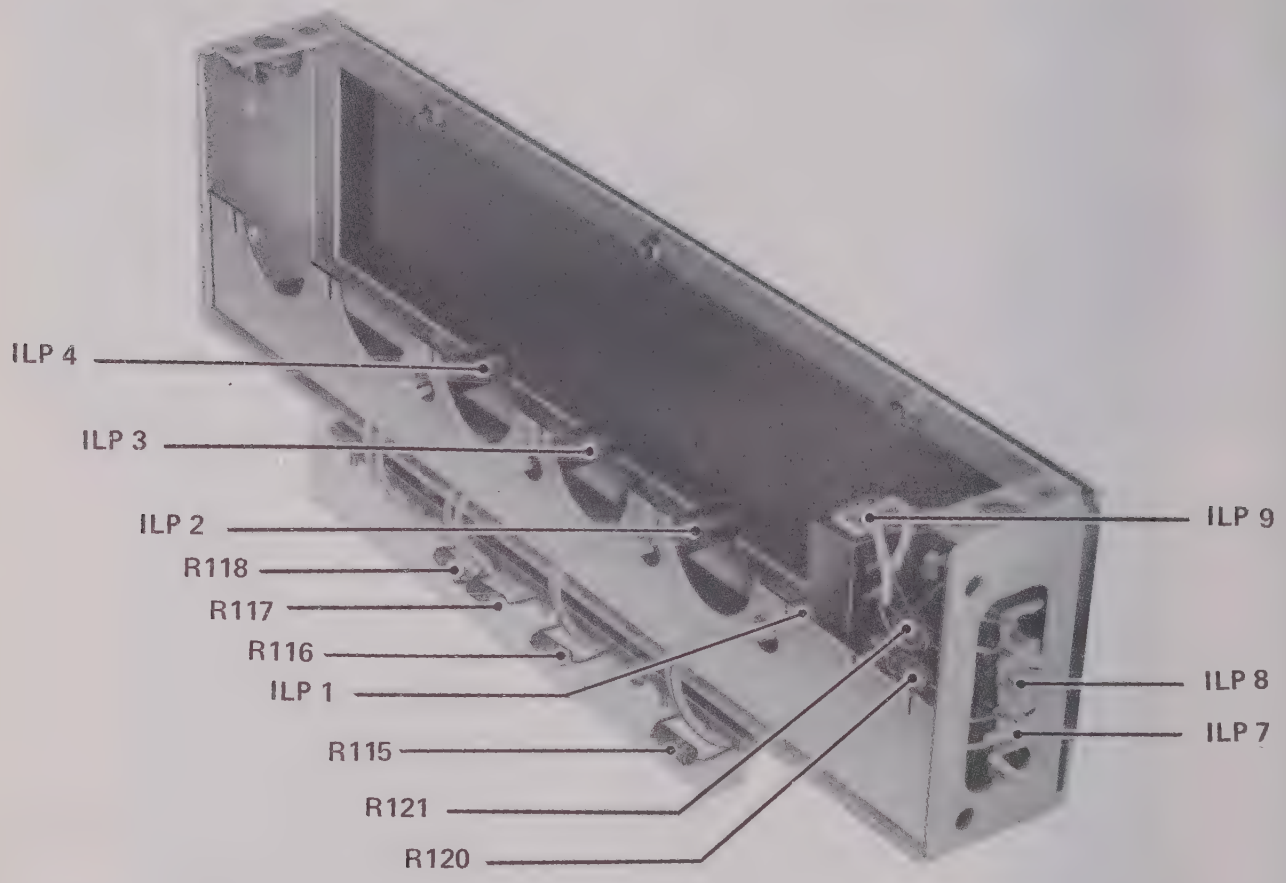
LM1867 Underside View



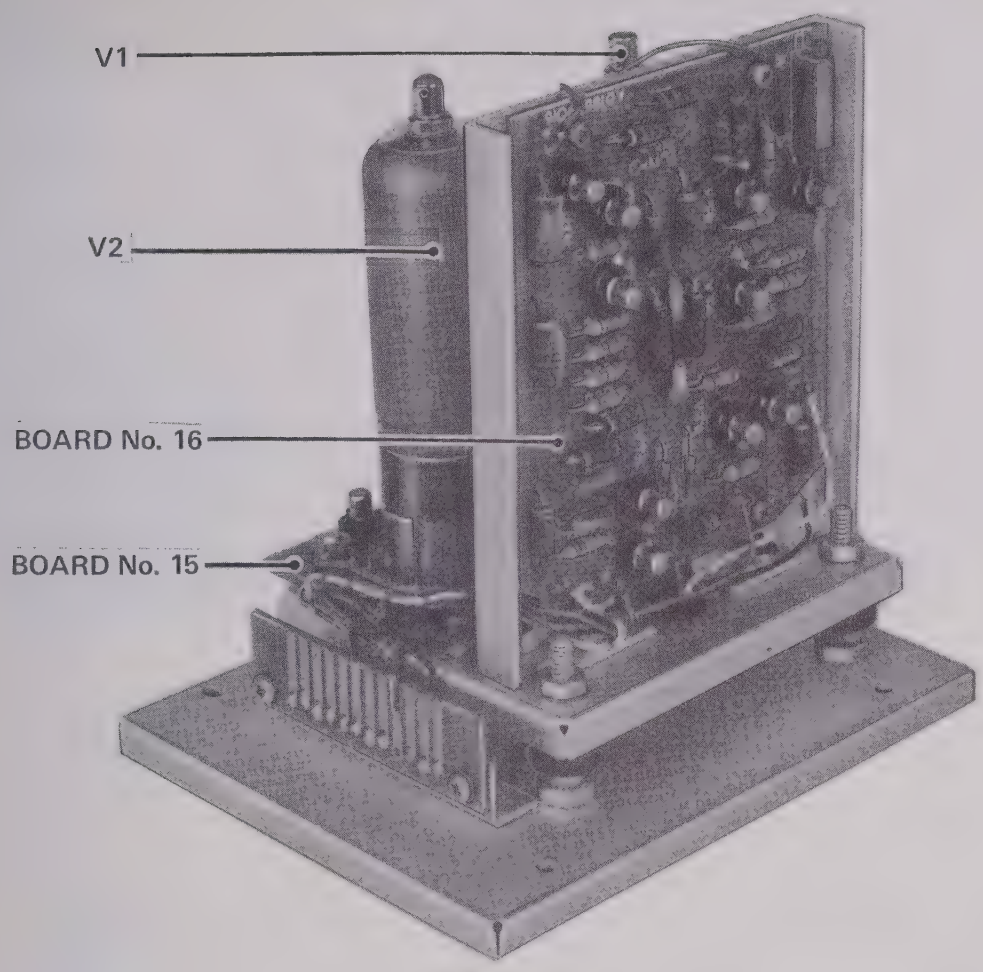
LM1867 Rear View (Without Fan-Out Unit)

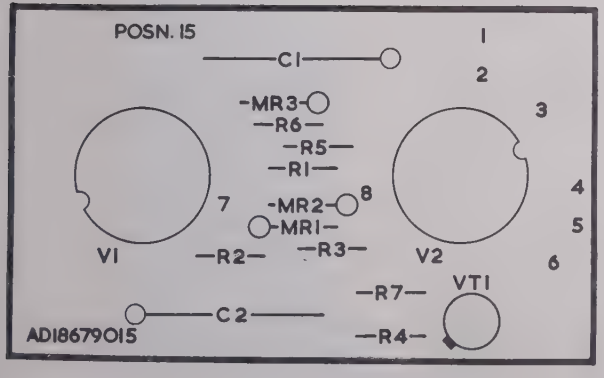


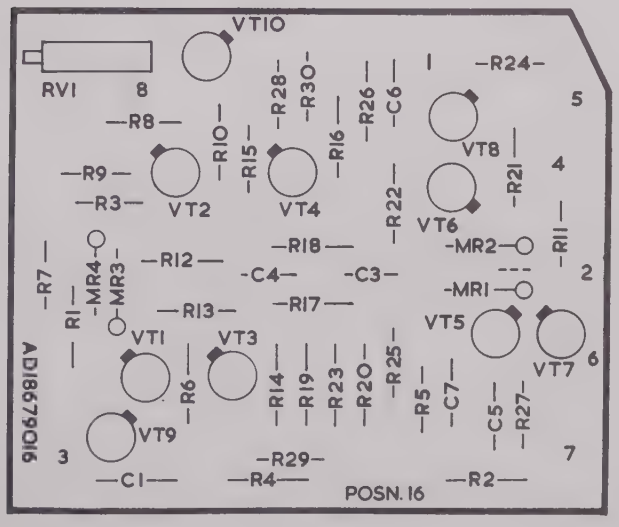
LM1867 Right Side Chassis



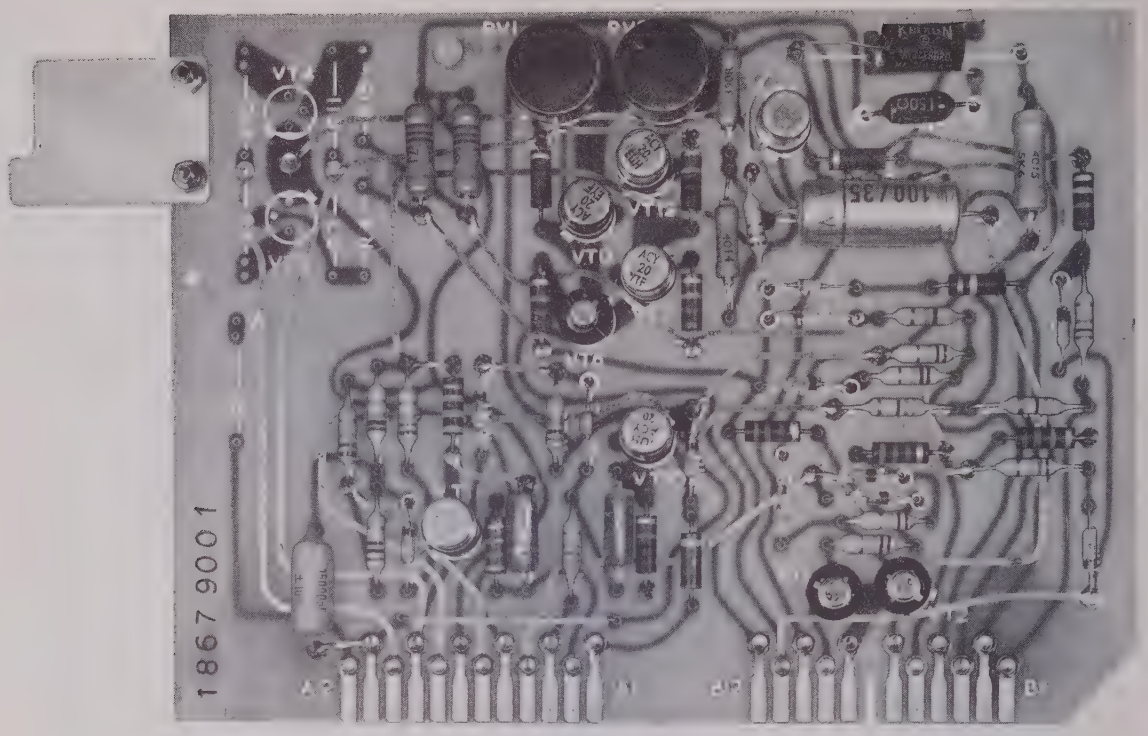
LM1867 Indicator Lamp Assembly – Rear View

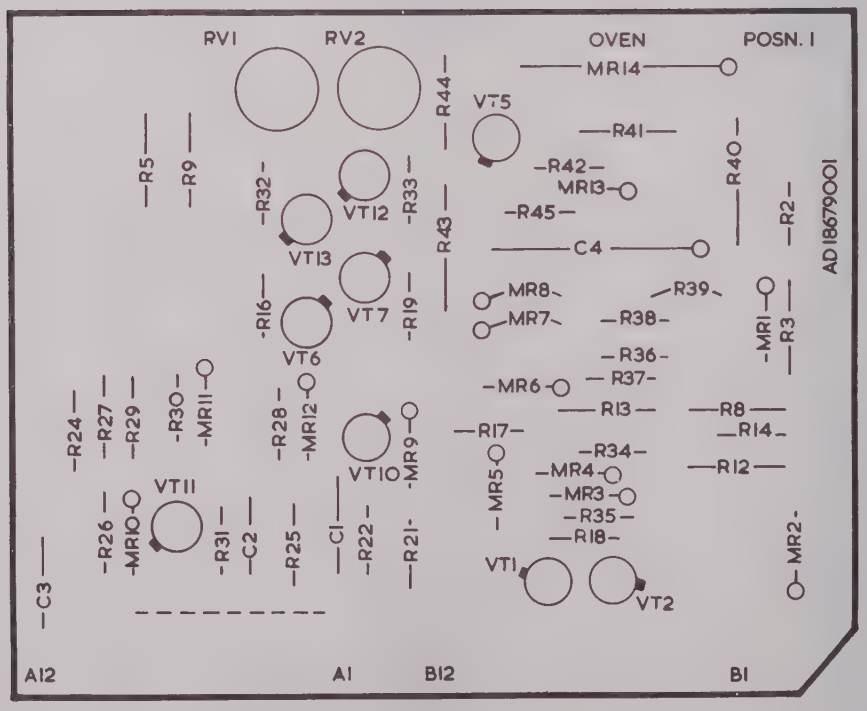




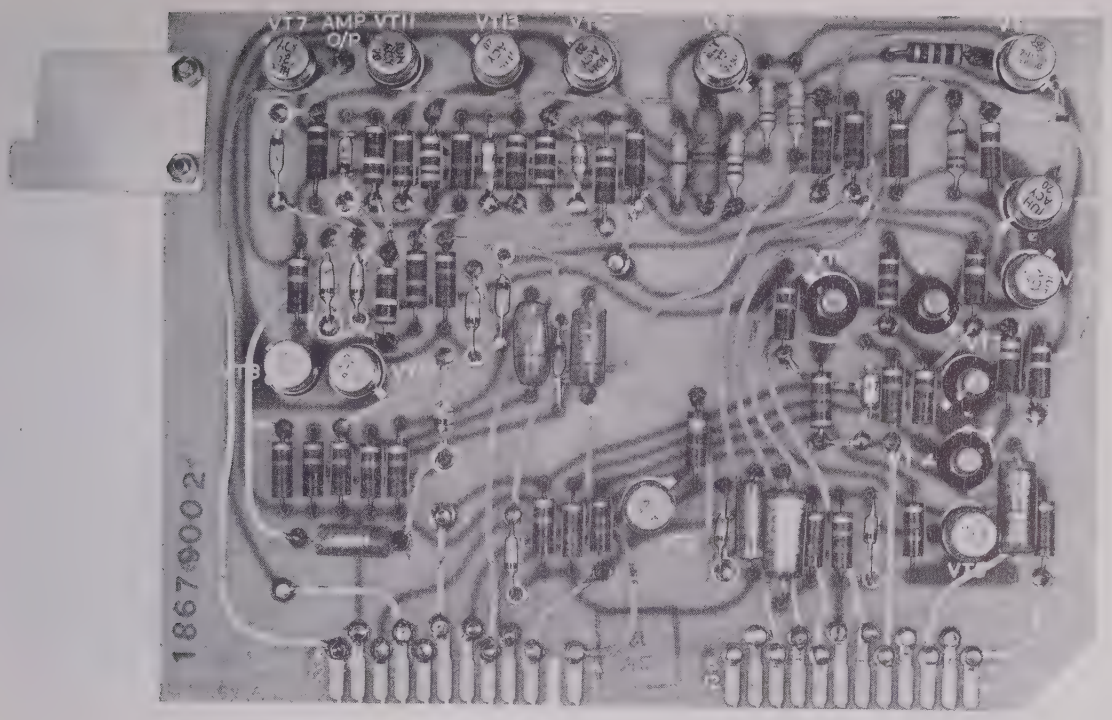


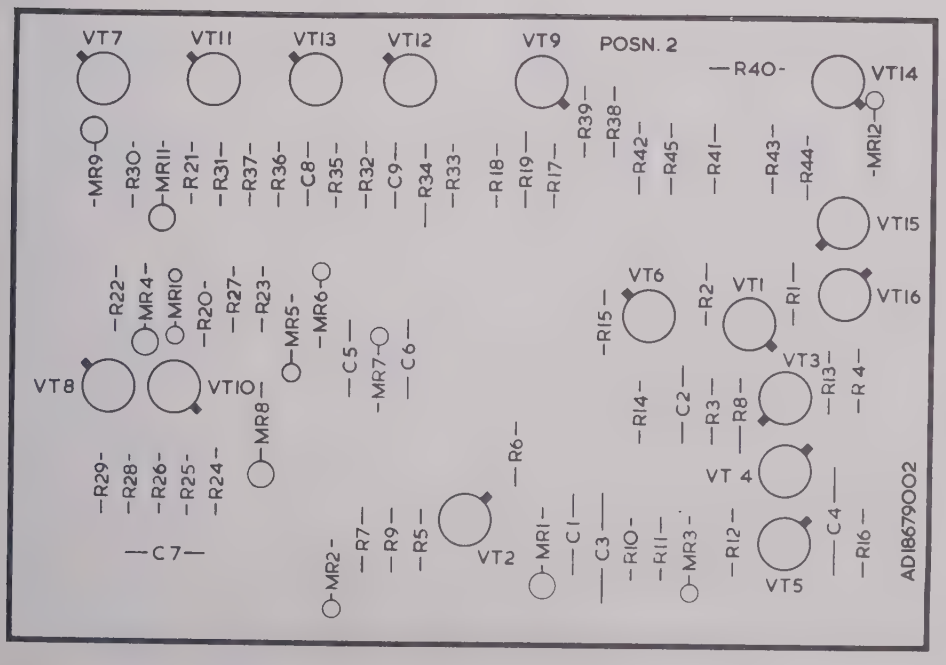
Input and Balance Amplifier Sub Chassis and Printed Circuit Board Nos 15 and 16



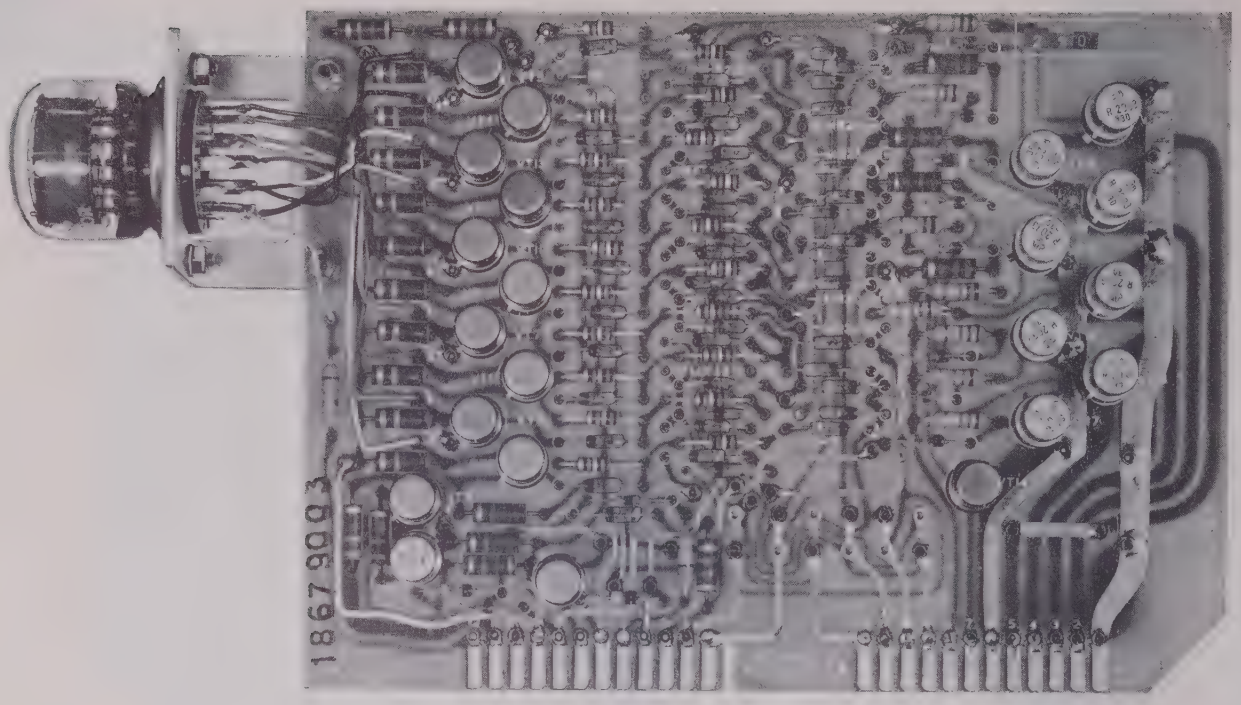


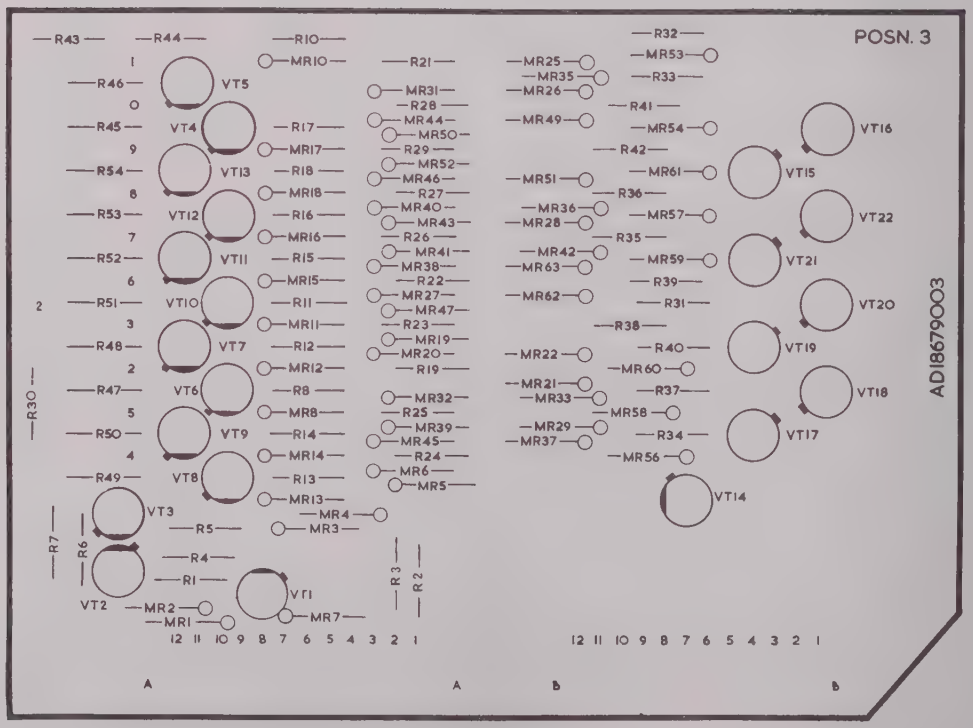
Printed Circuit Board 18679001



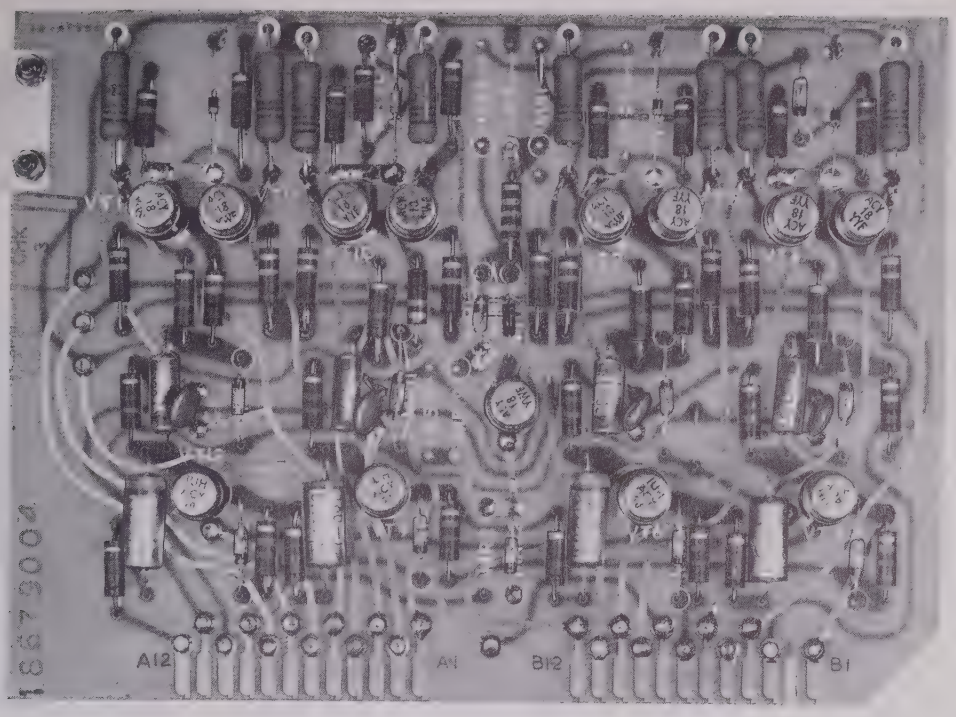


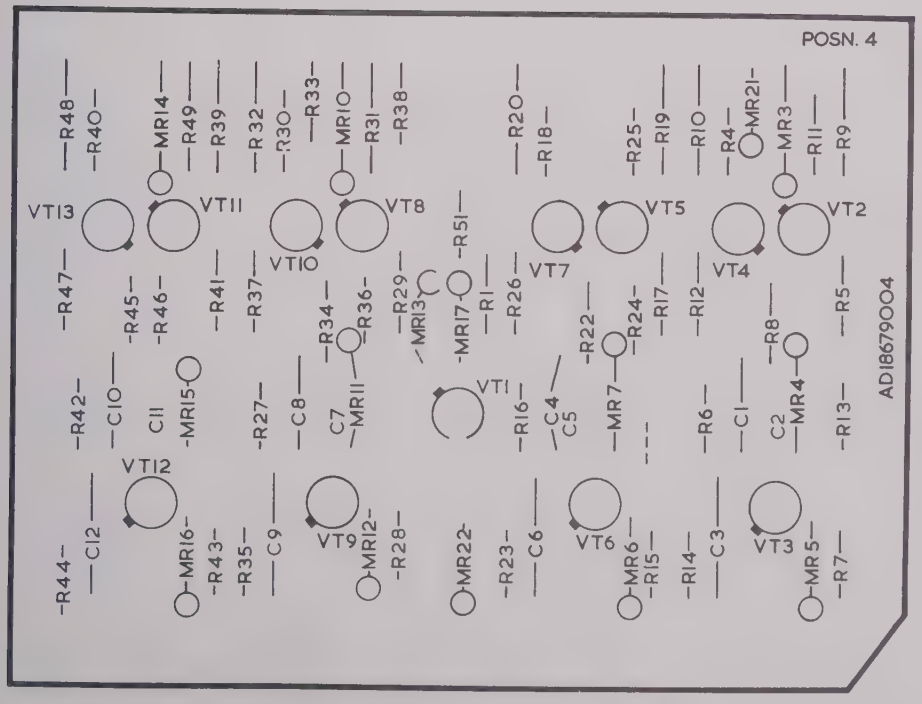
Printed Circuit Board 18679002



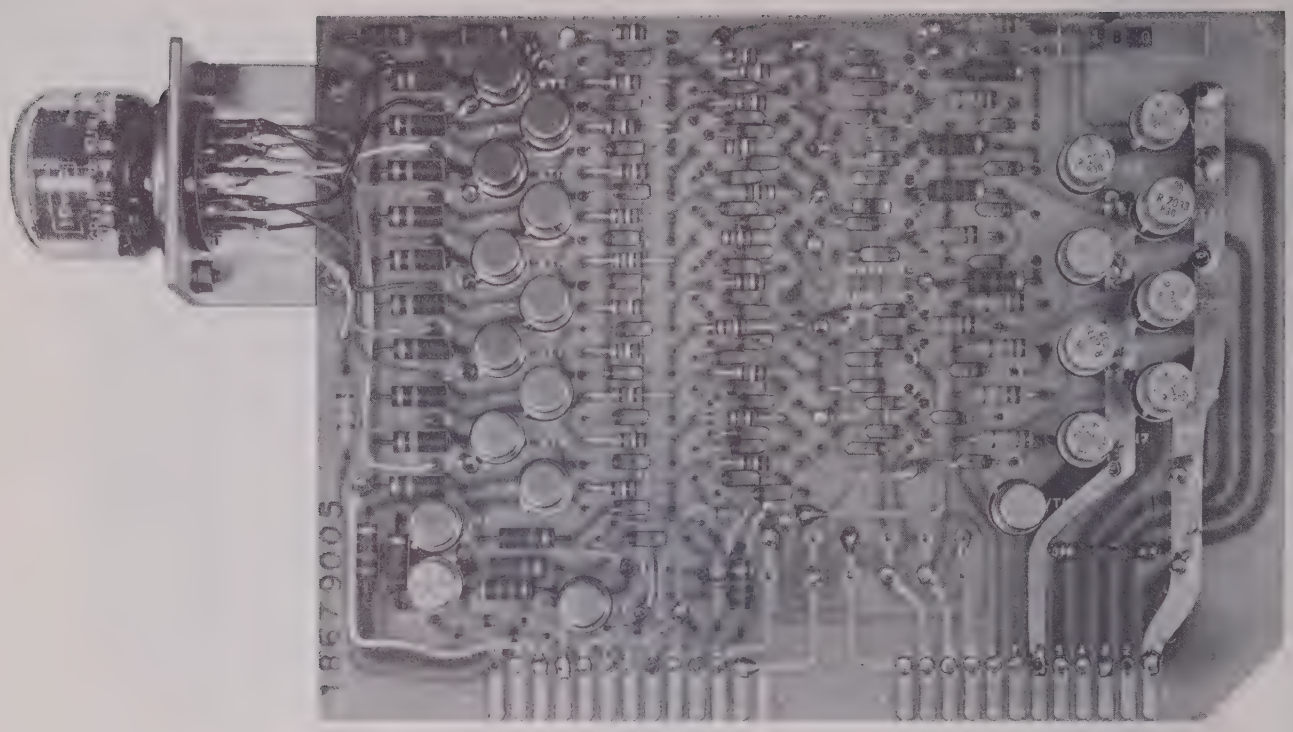


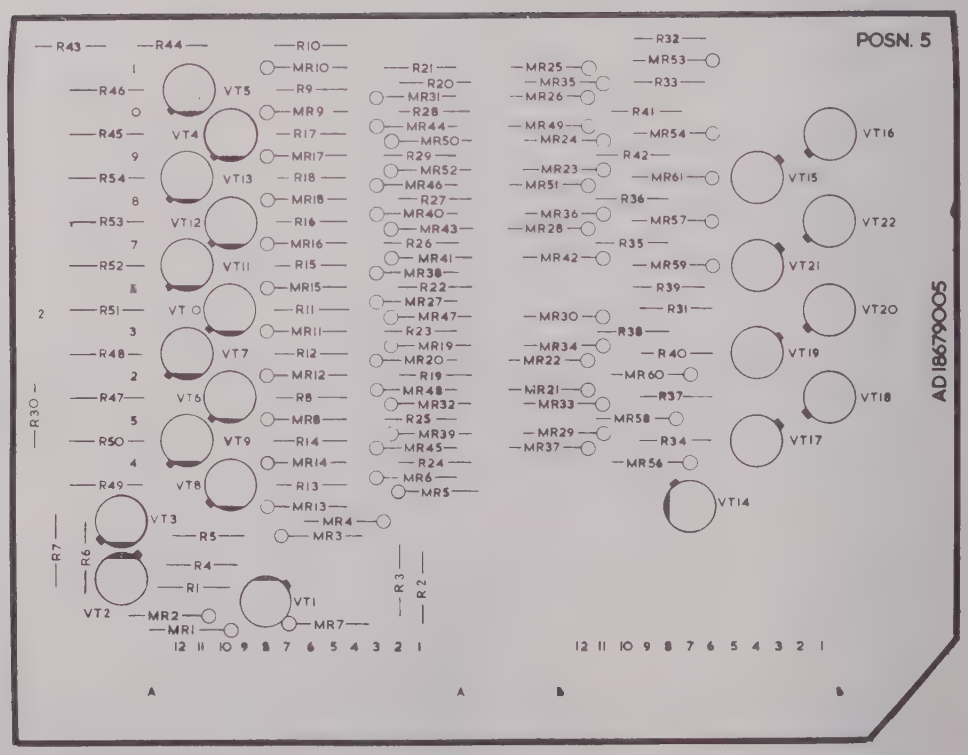
Printed Circuit Board 18679003



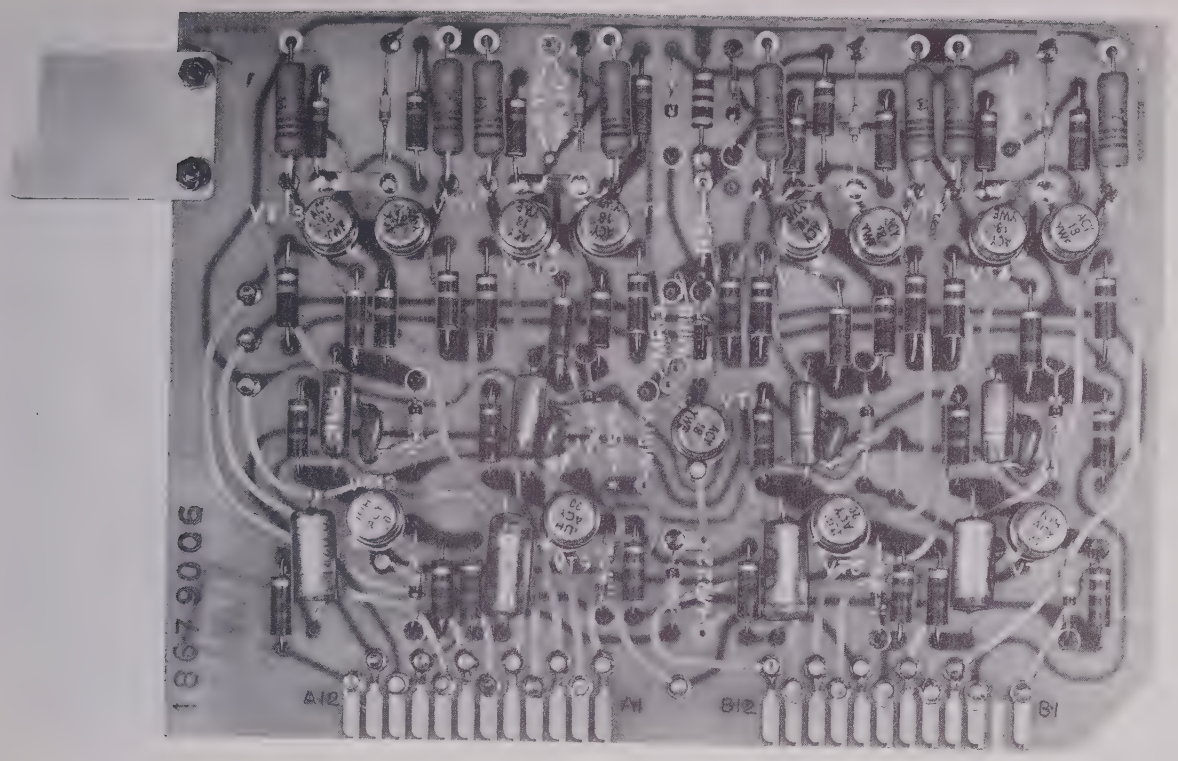


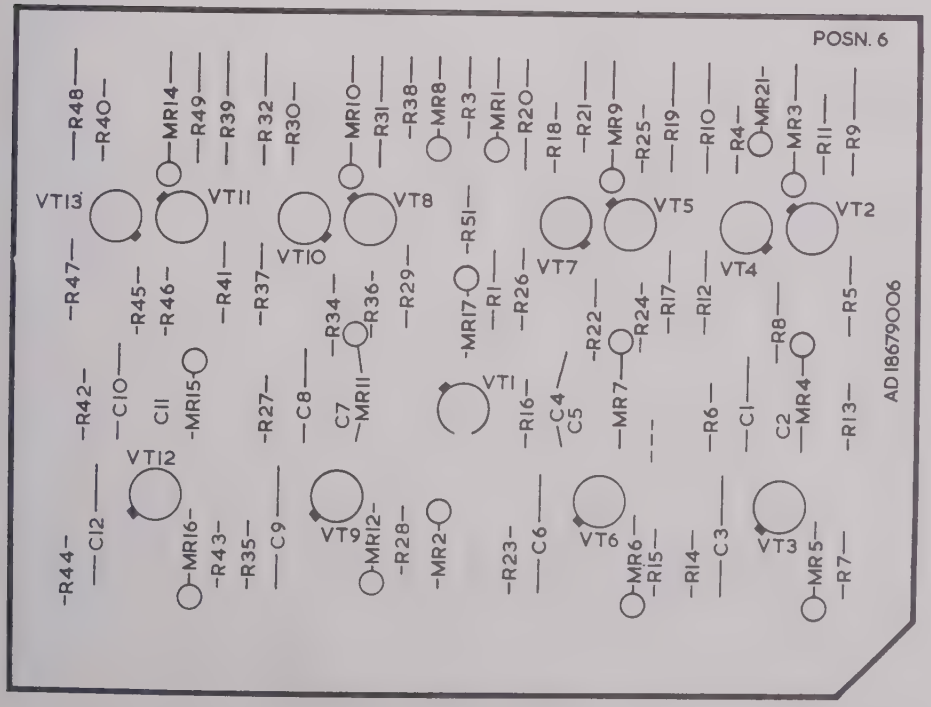
Printed Circuit Board 18679004



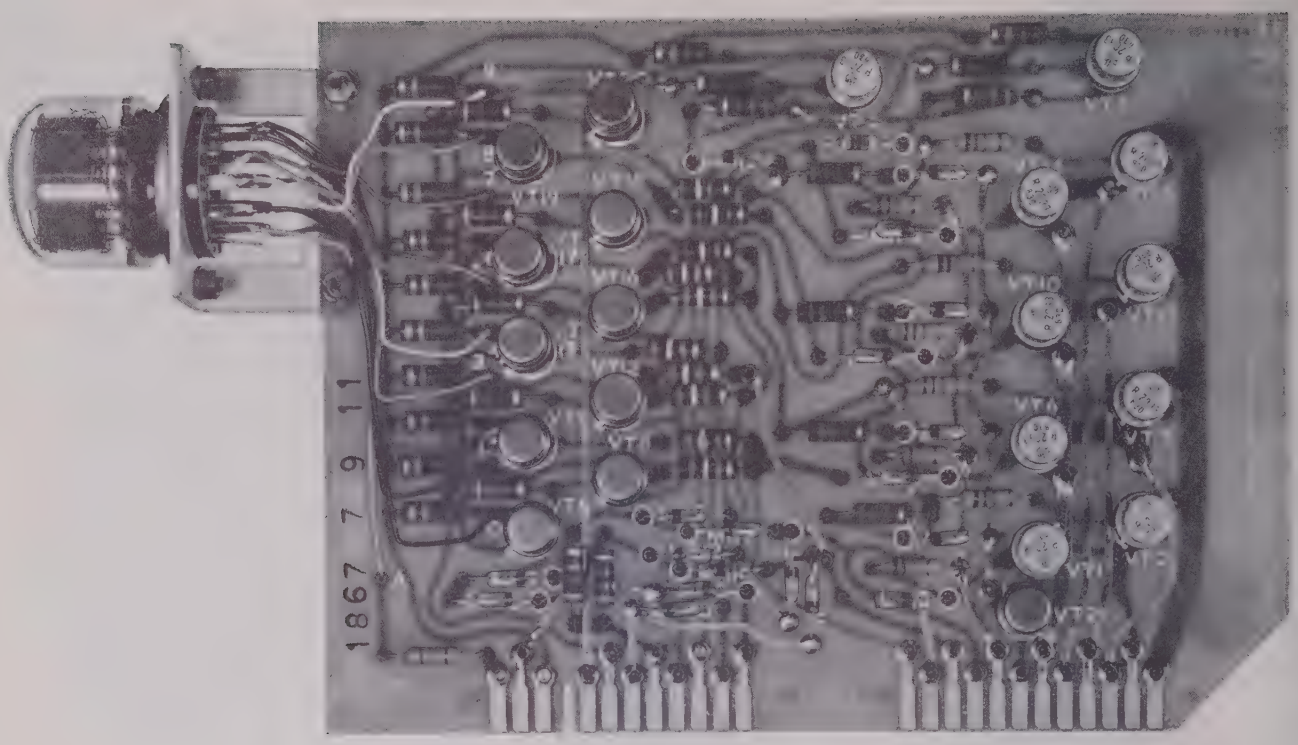


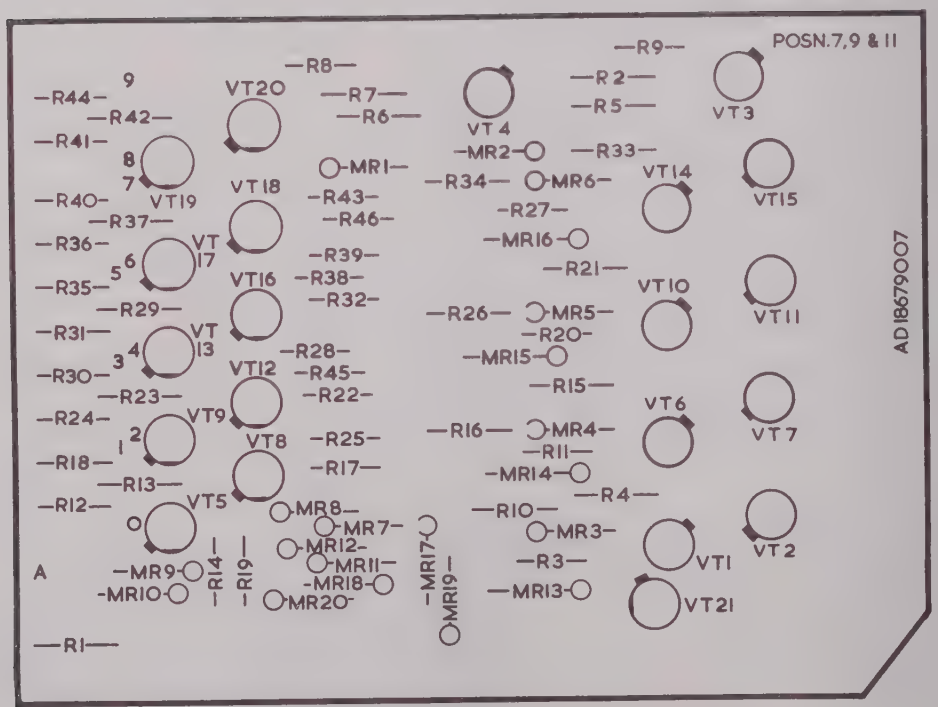
Printed Circuit Board 18679005



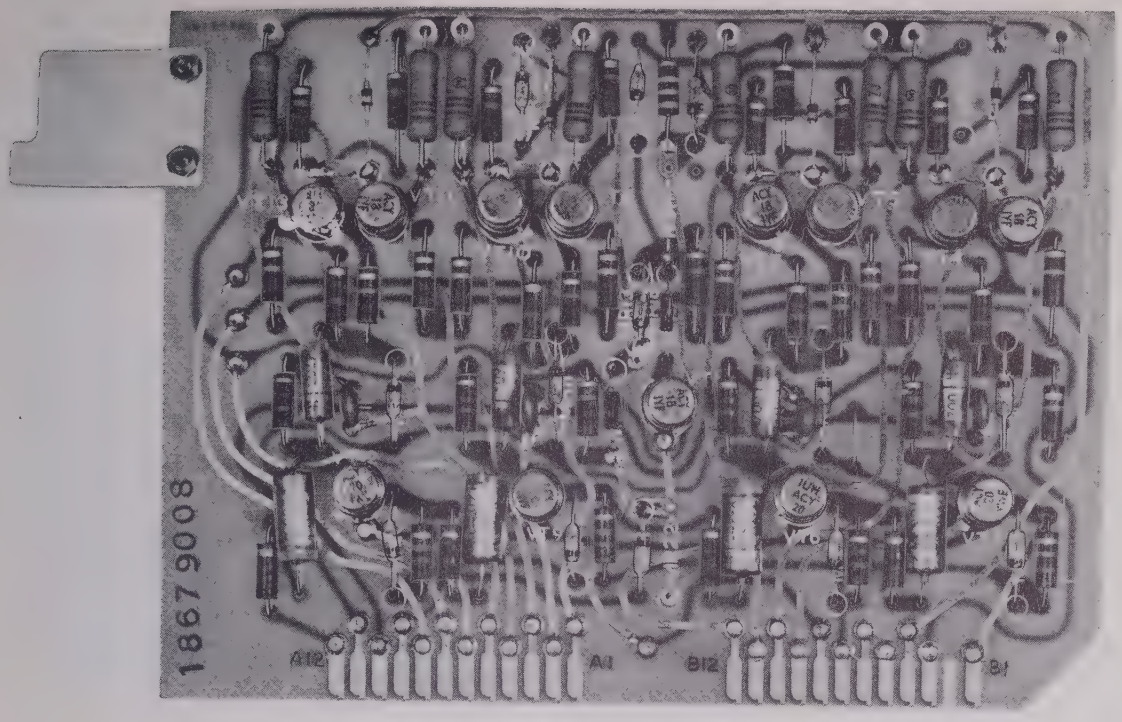


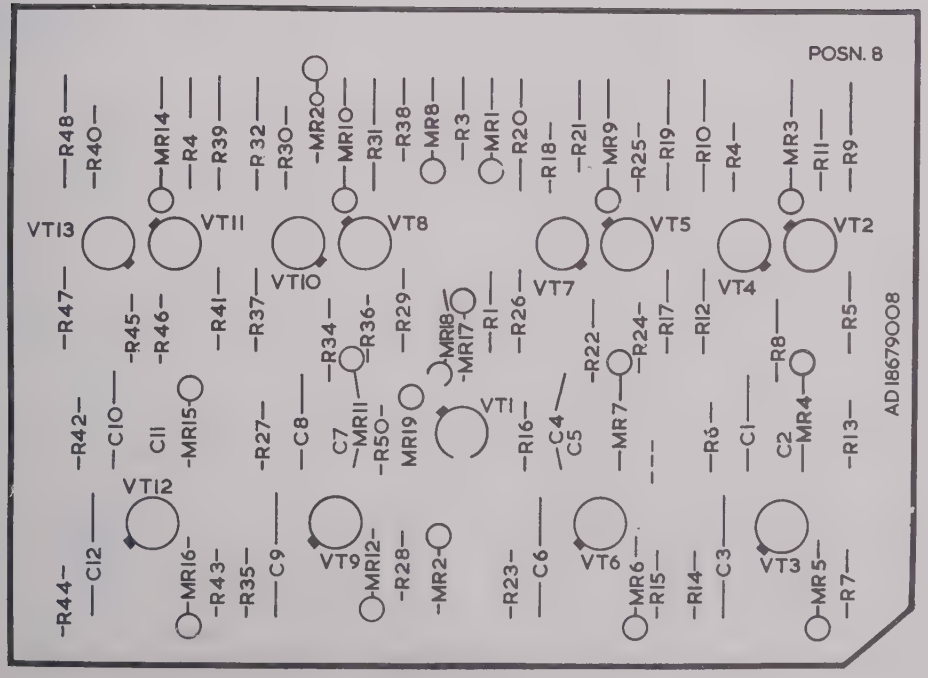
Printed Circuit Board 18679006





Printed Circuit Board 18679007 (Used in Positions 7, 9 and 11)

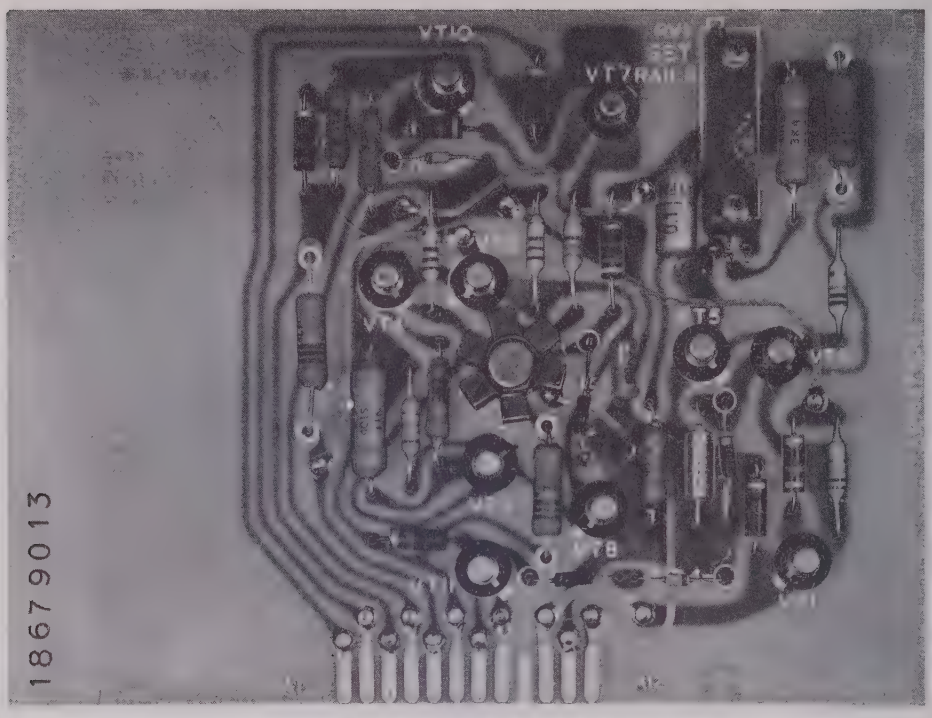


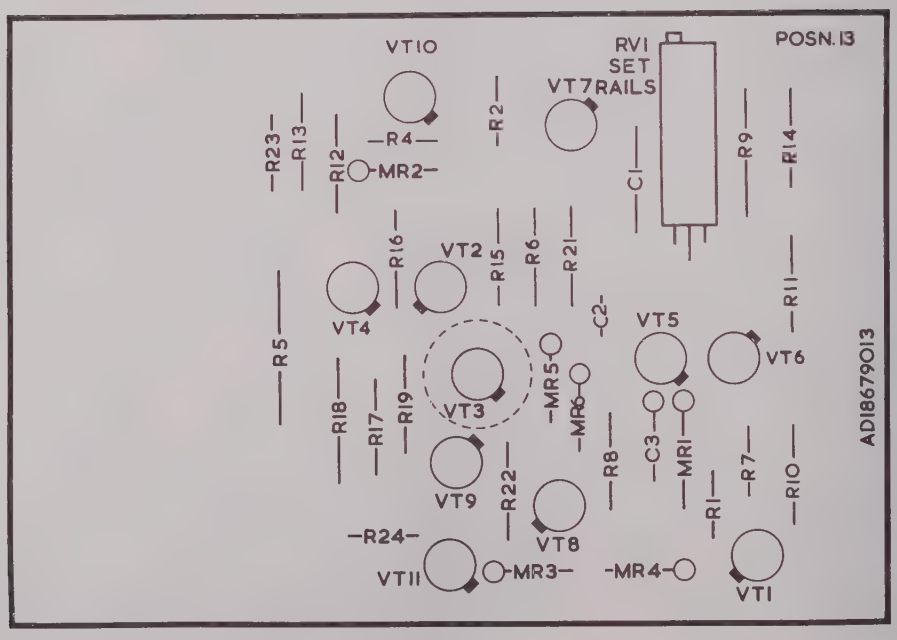


Printed Circuit Board 18679008

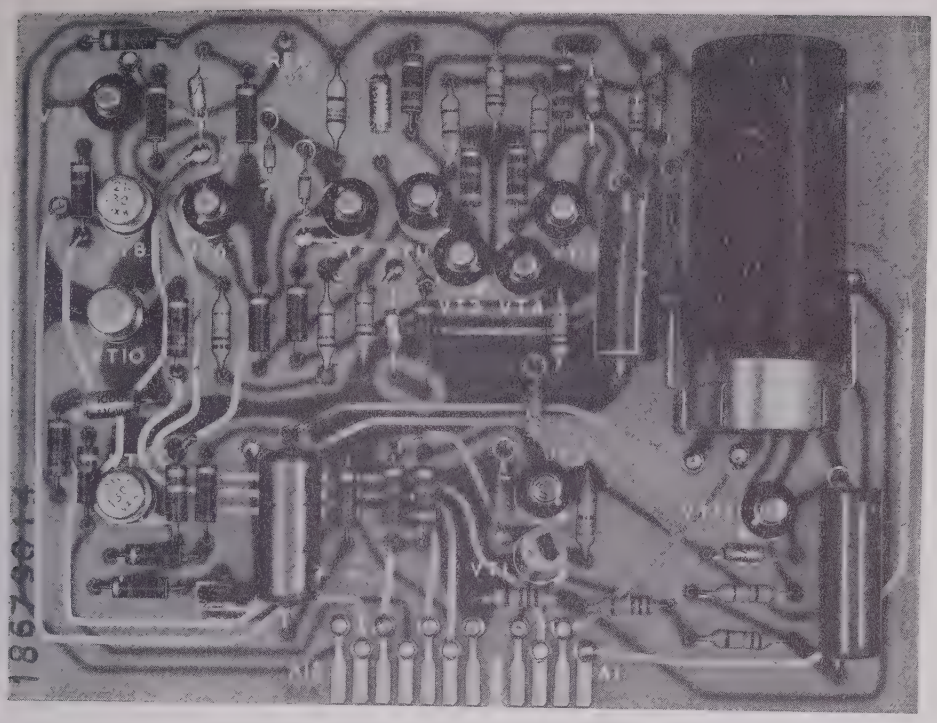
Printed Circuit Board 18679010

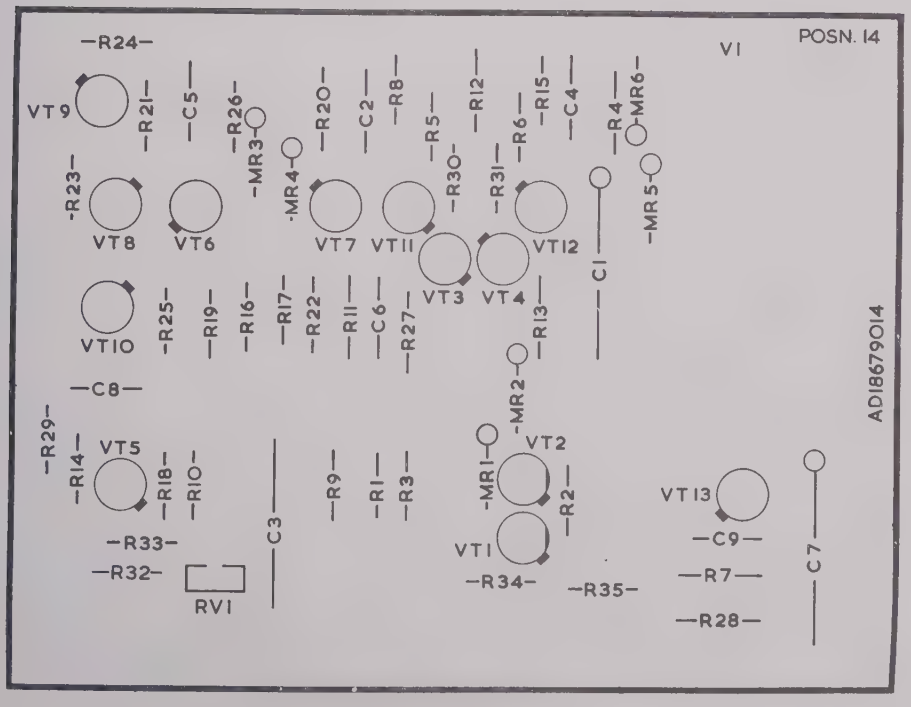
Printed Circuit Board 18679012



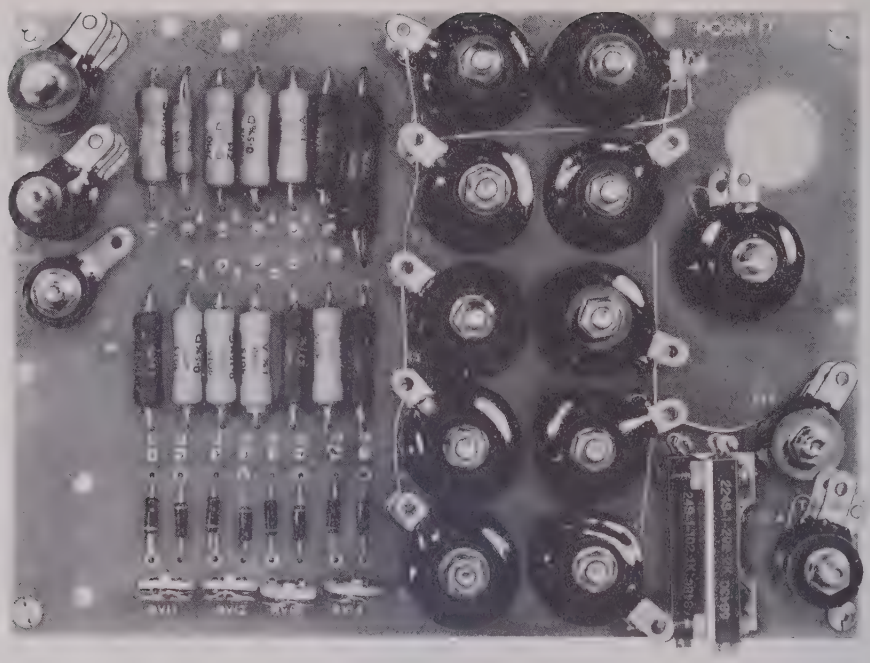


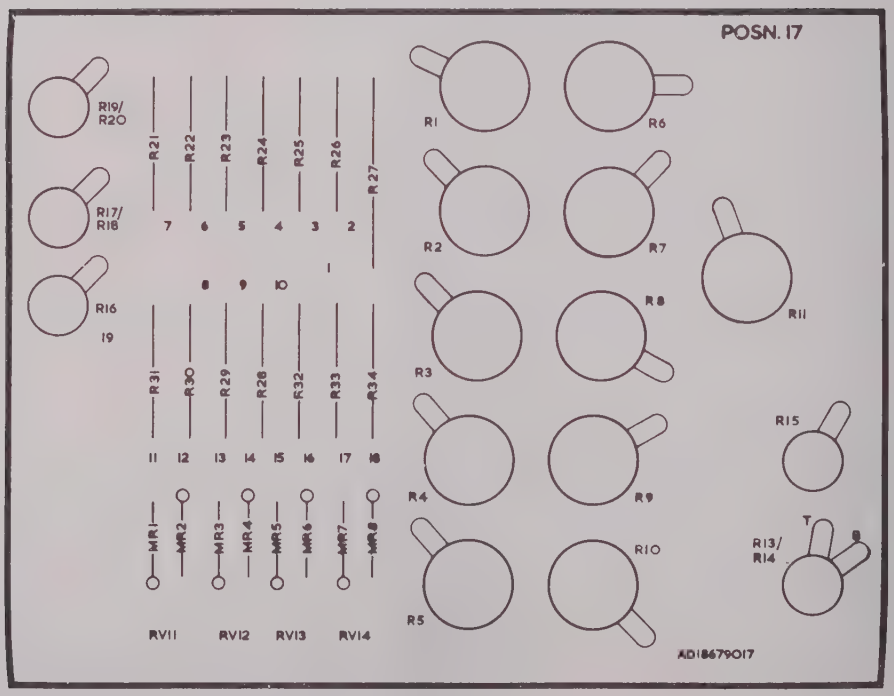
Printed Circuit Board 18679013



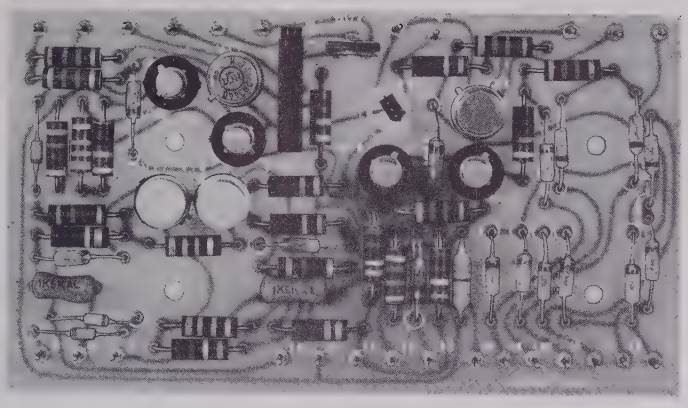


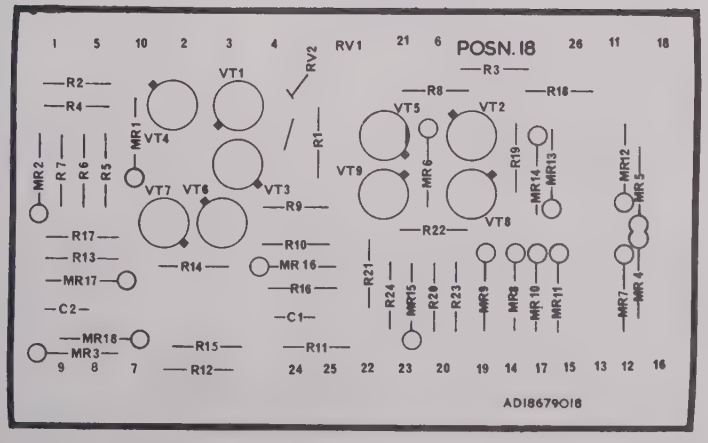
Printed Circuit Board 18679014



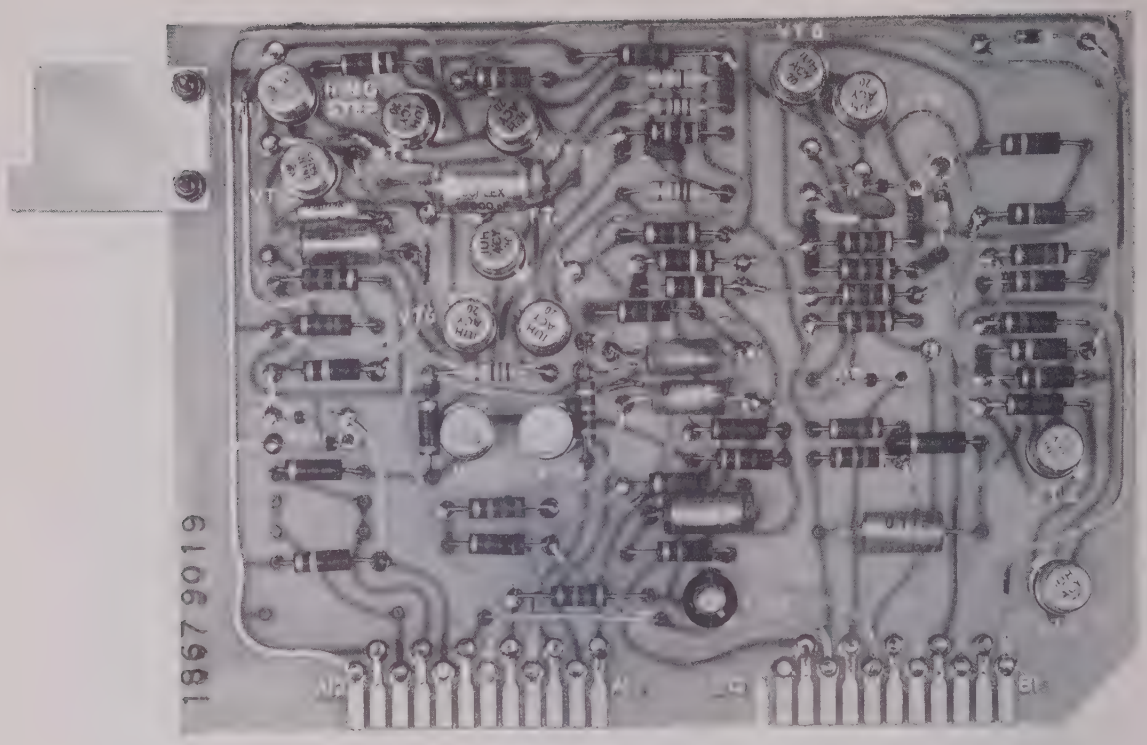


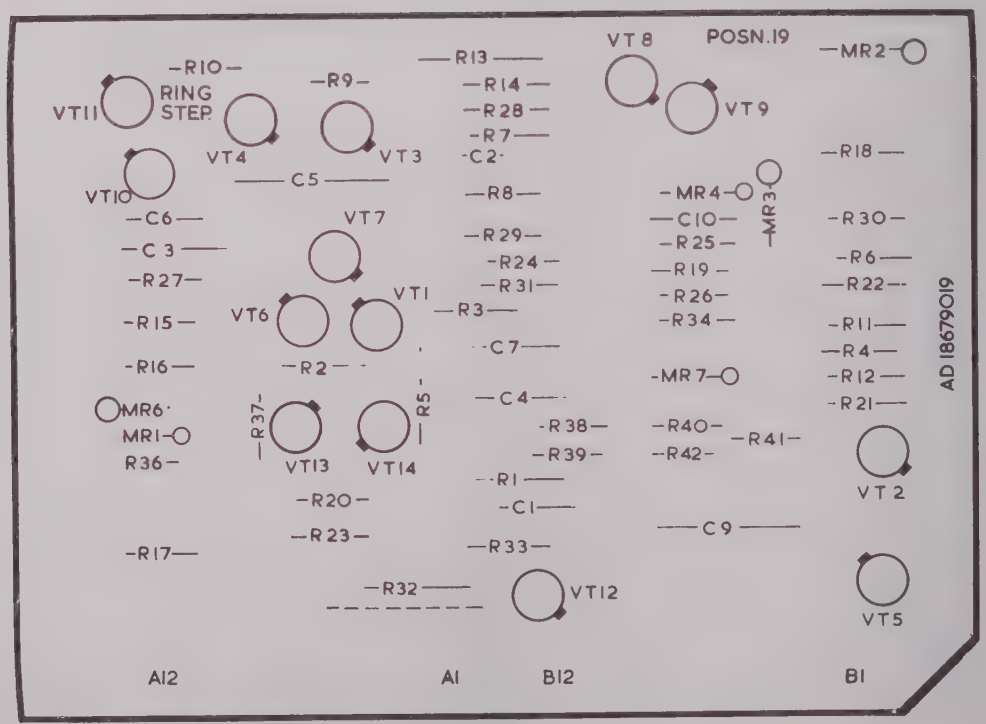
Printed Circuit Board 18679017



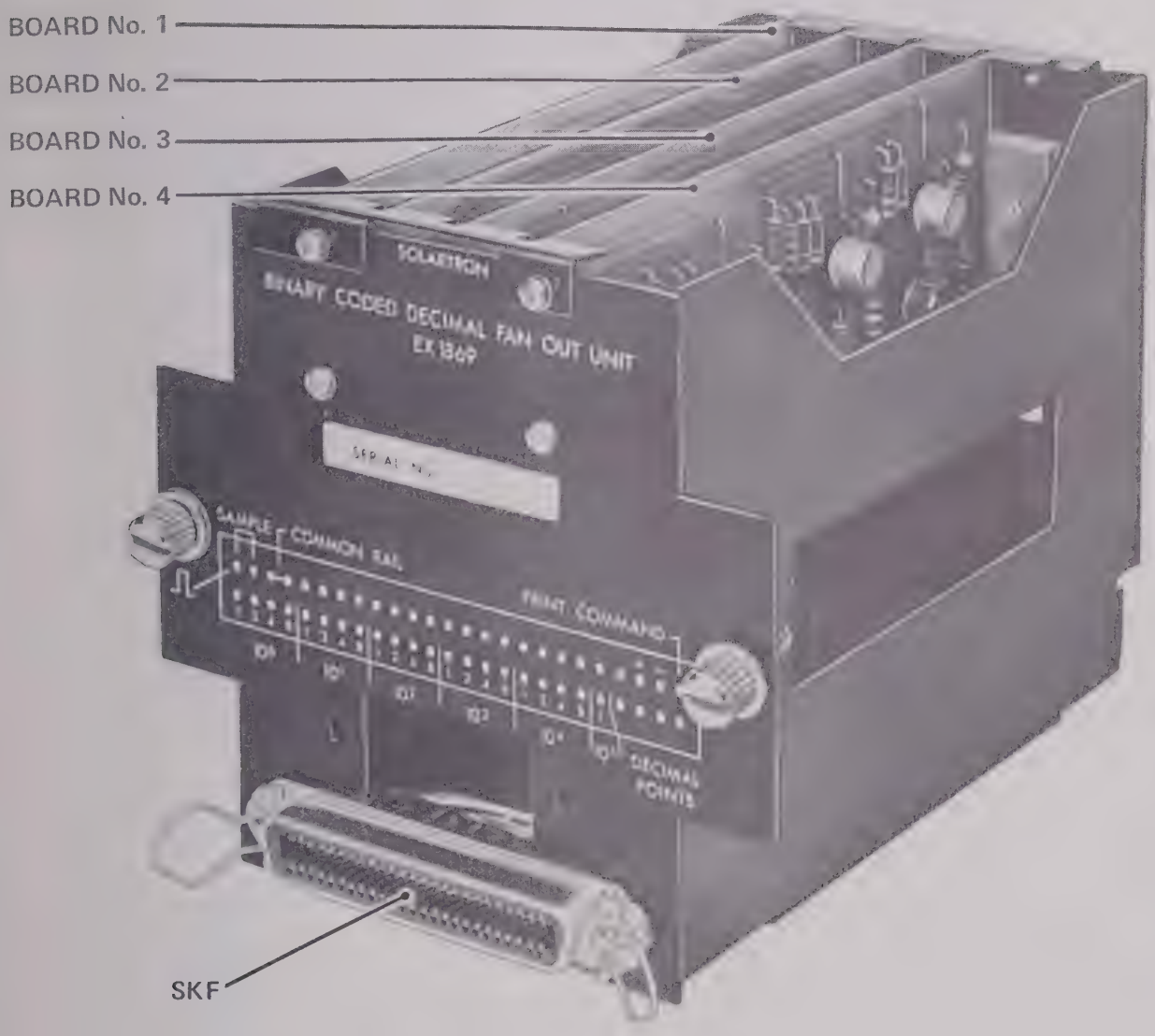


Printed Circuit Board 18679018

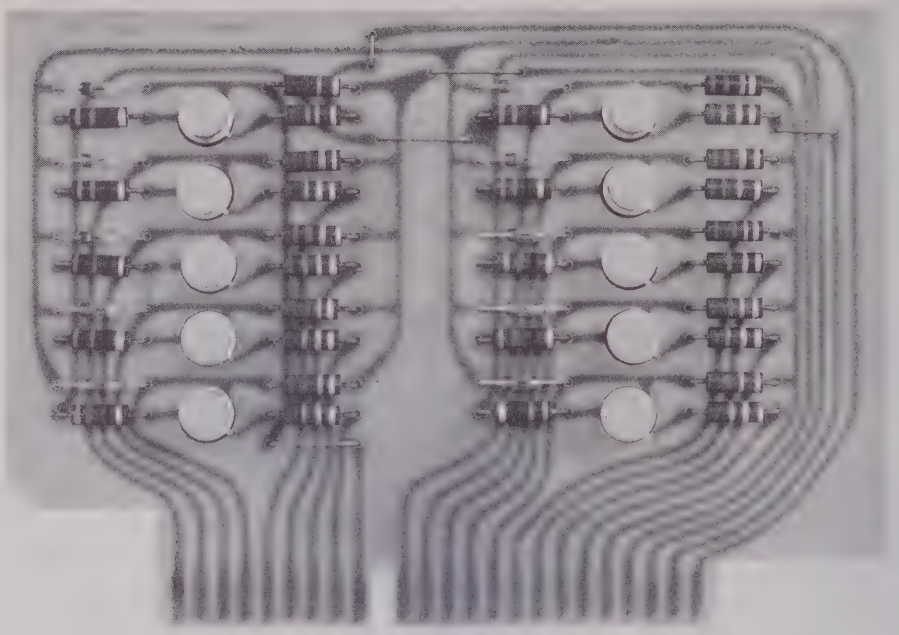


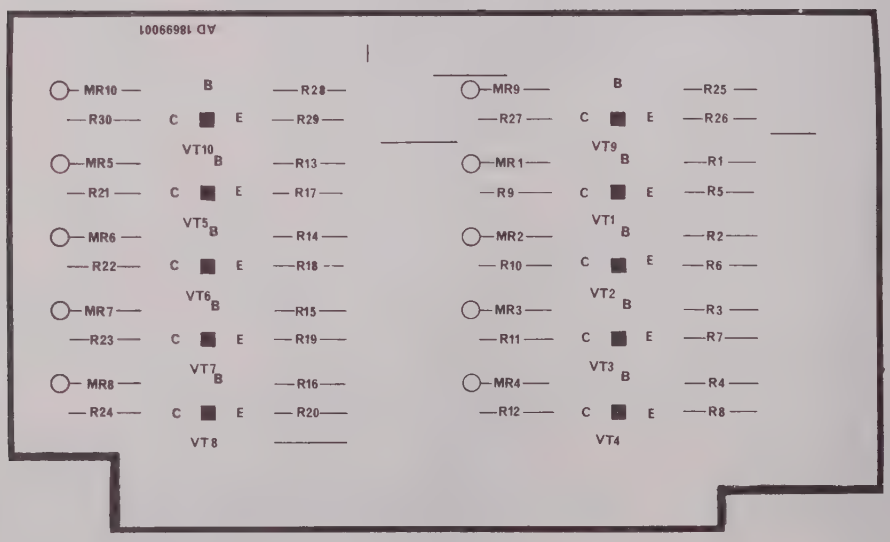


Printed Circuit Board 18679019

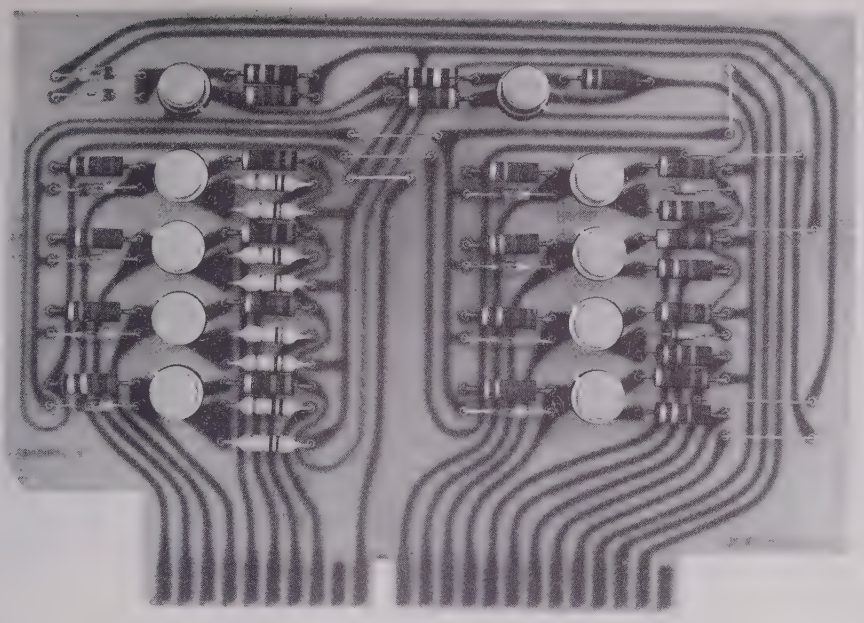


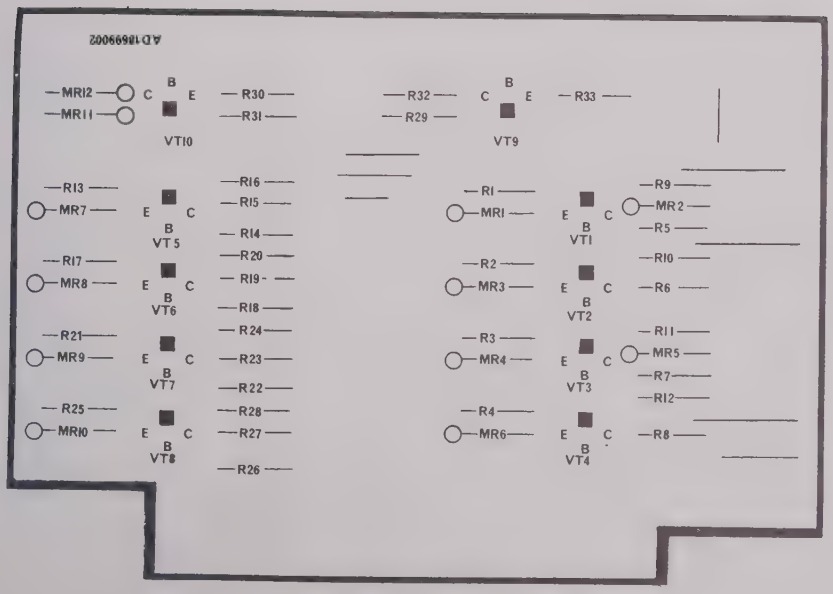
EX1869 Fan-Out Unit



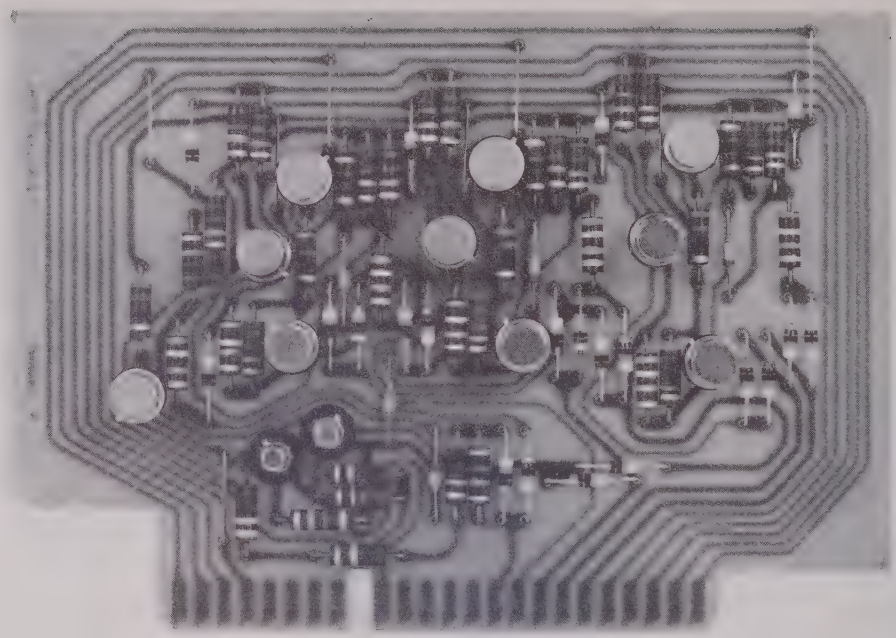


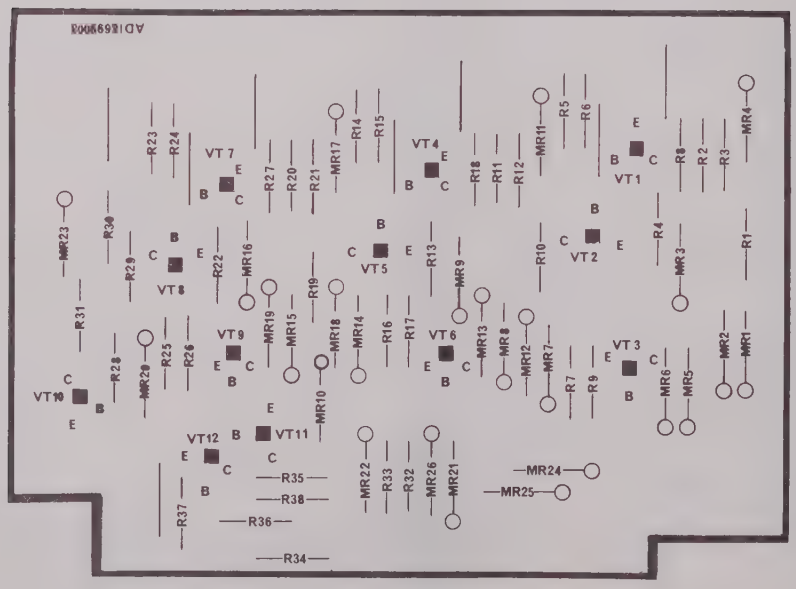
Printed Circuit Board 18699001



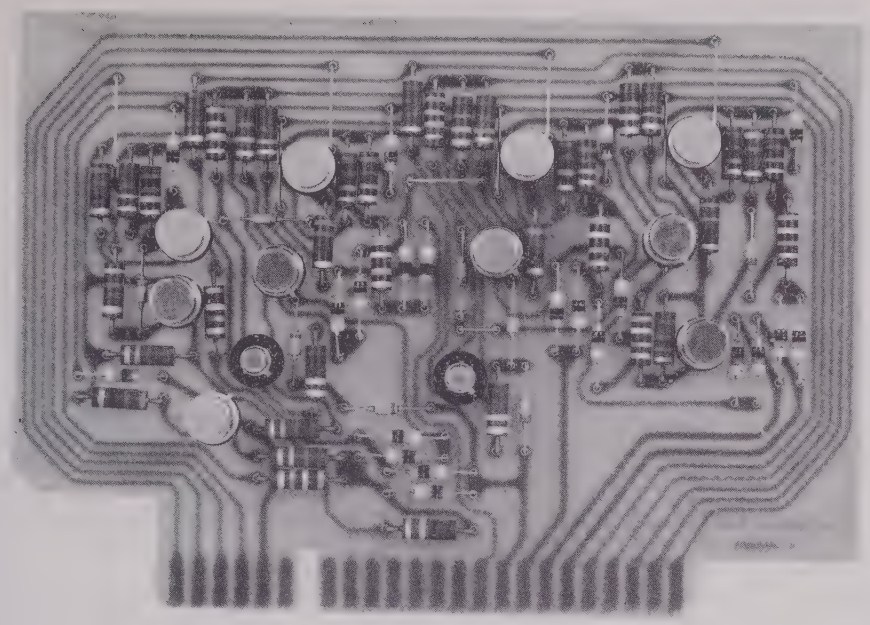


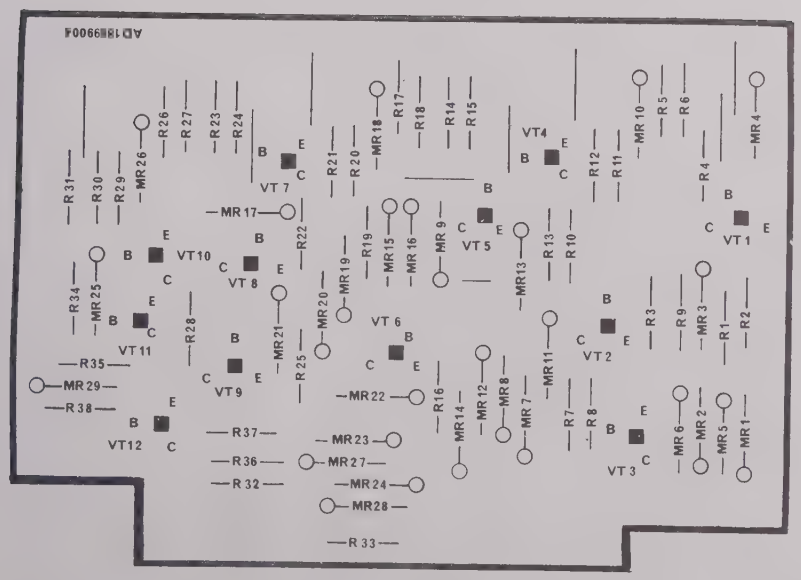
Printed Circuit Board 18699002



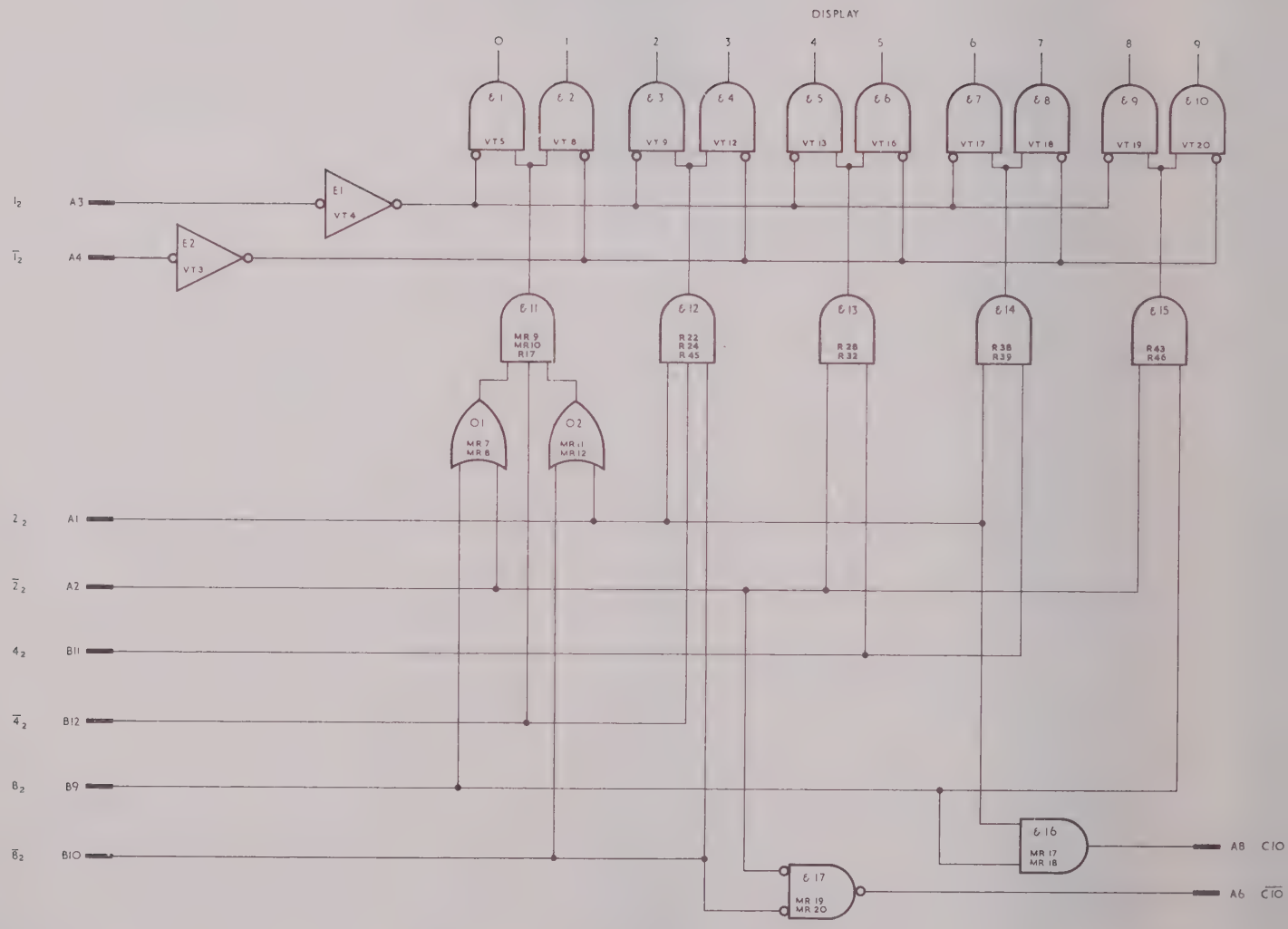


Printed Circuit Board 18699003



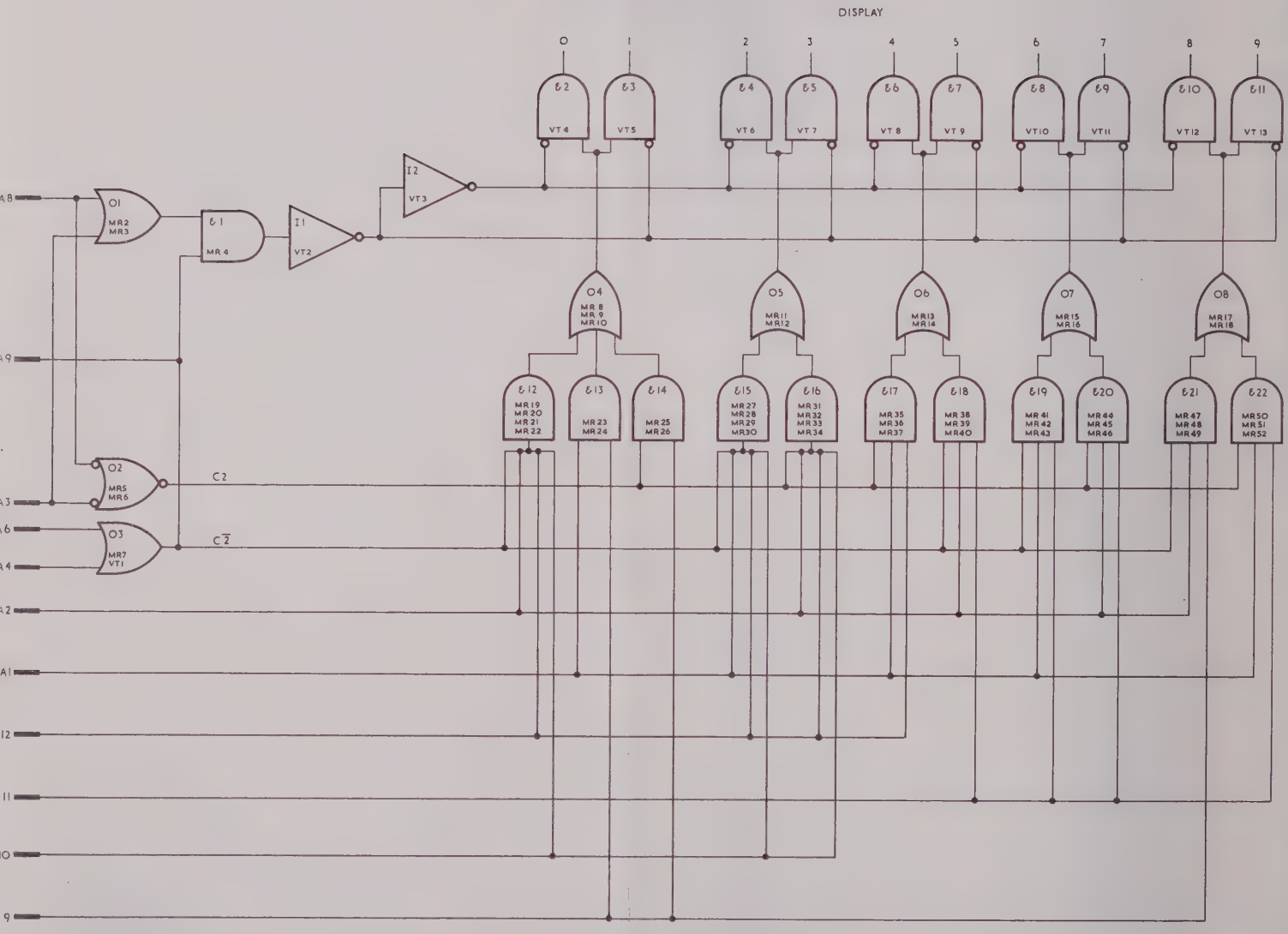


Printed Circuit Board 18699004



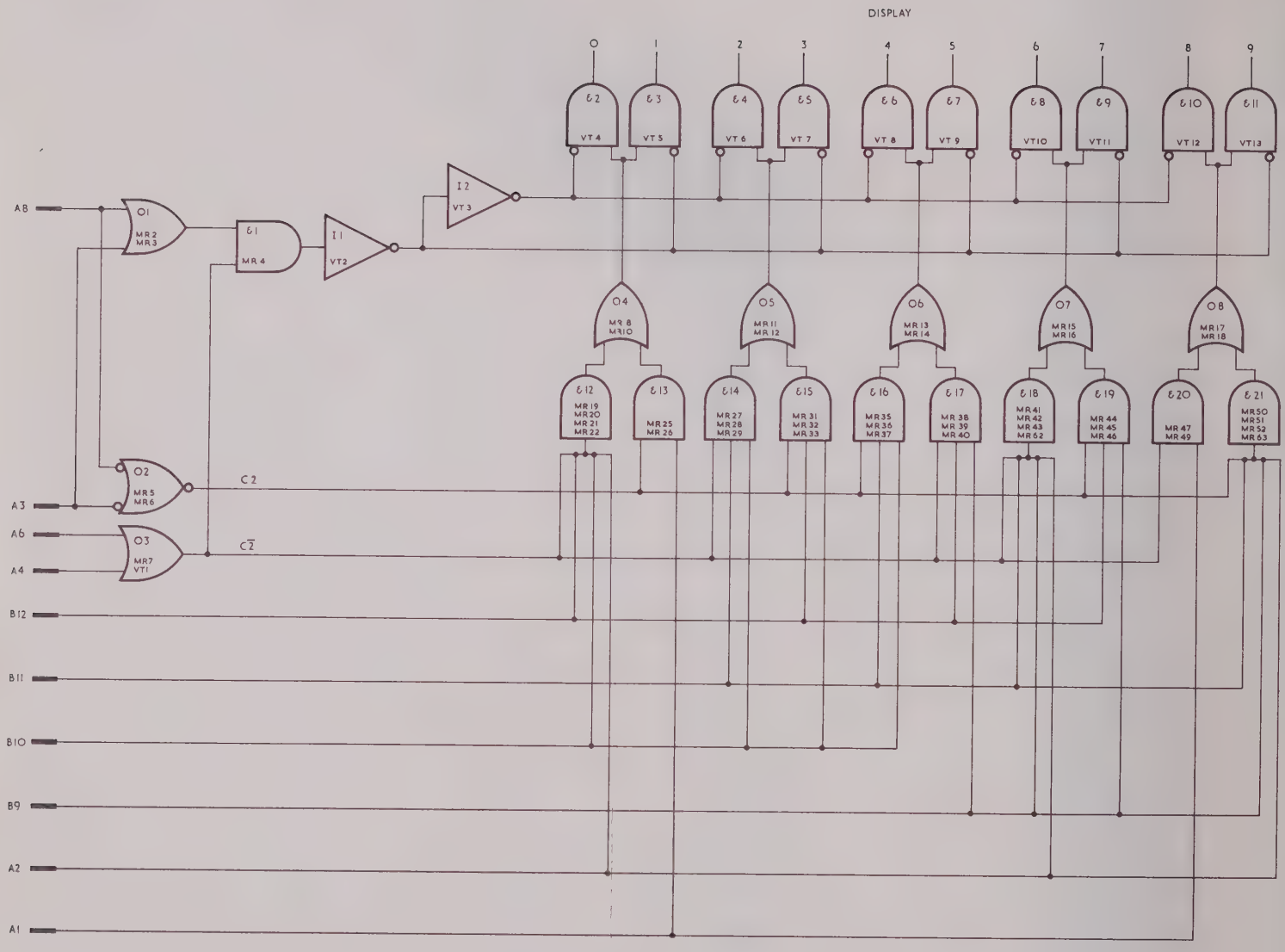
Logic Diagram 1

10^2 Decode Circuitry - Board No. 18679007



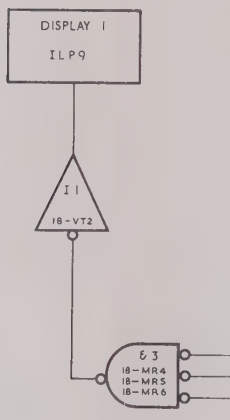
Logic Diagram 2

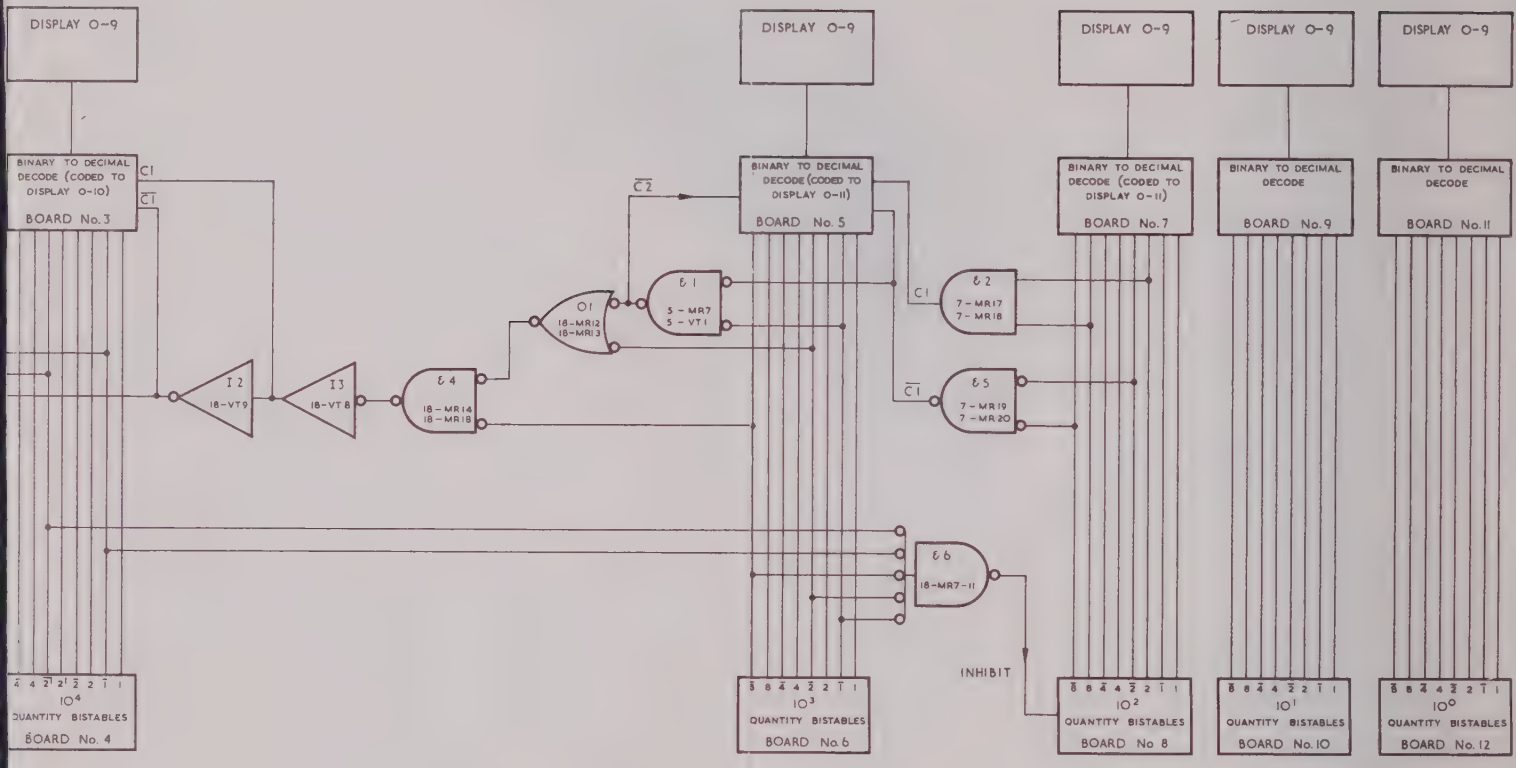
10^3 Decode Circuitry - Board No. 18679005



Logic Diagram 3

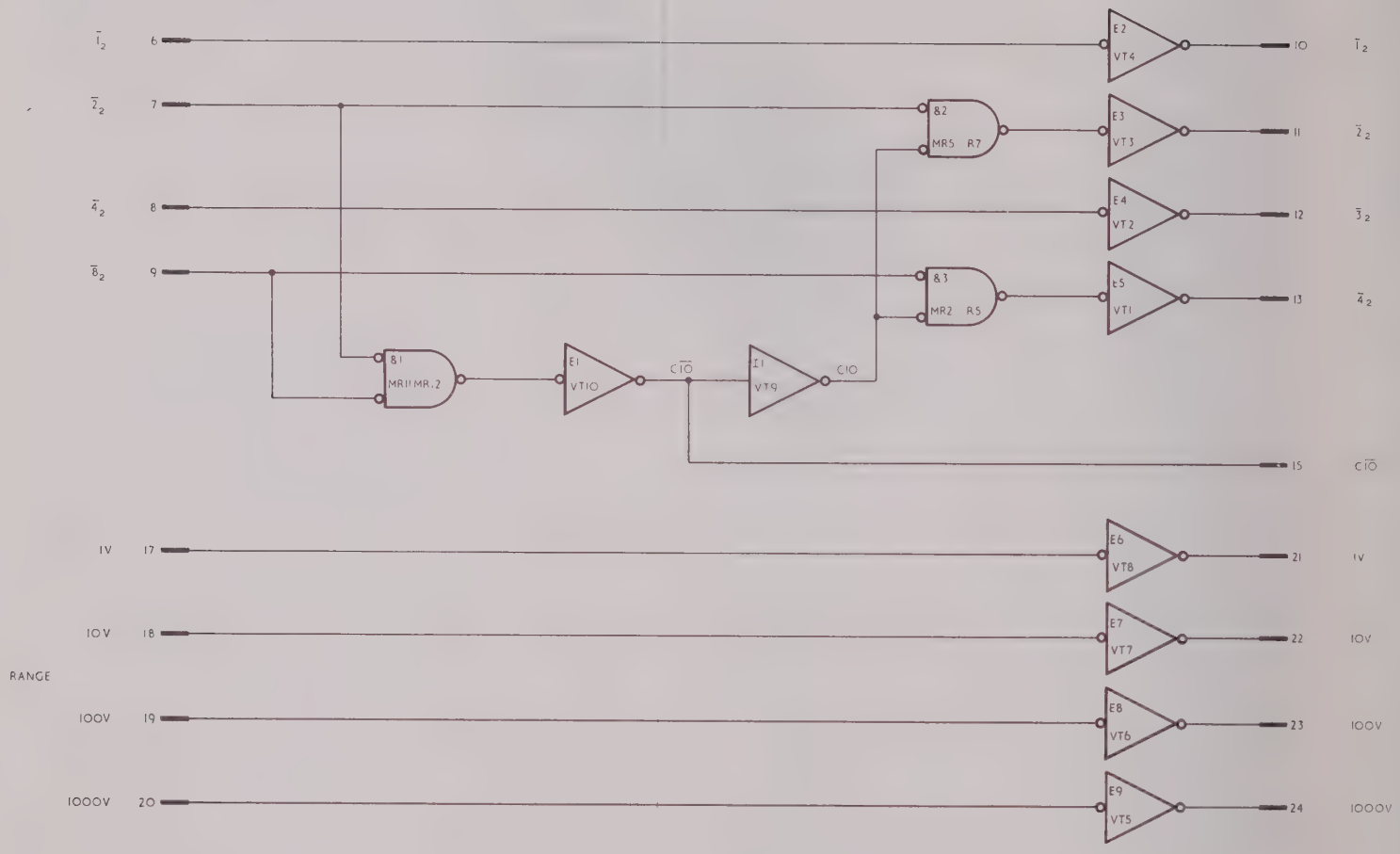
10^4 Decode Circuitry - Board No. 18679003


DISPLAY 1
ILP9
I 1
18-VT2
& 3
18-MR4
18-MR5
18-MR6



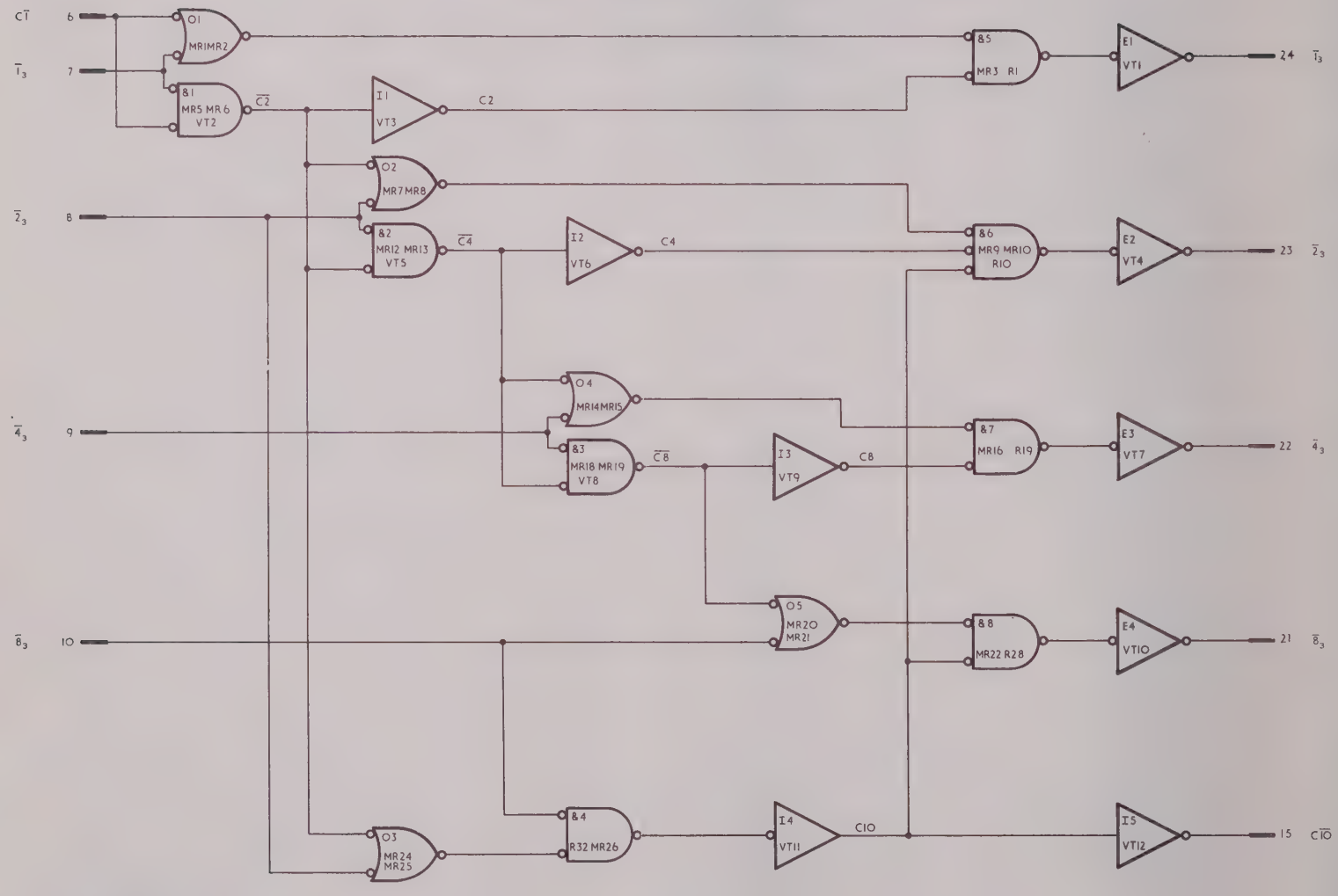
Logic Diagram 4

Digital Carry Logic



Logic Diagram 5

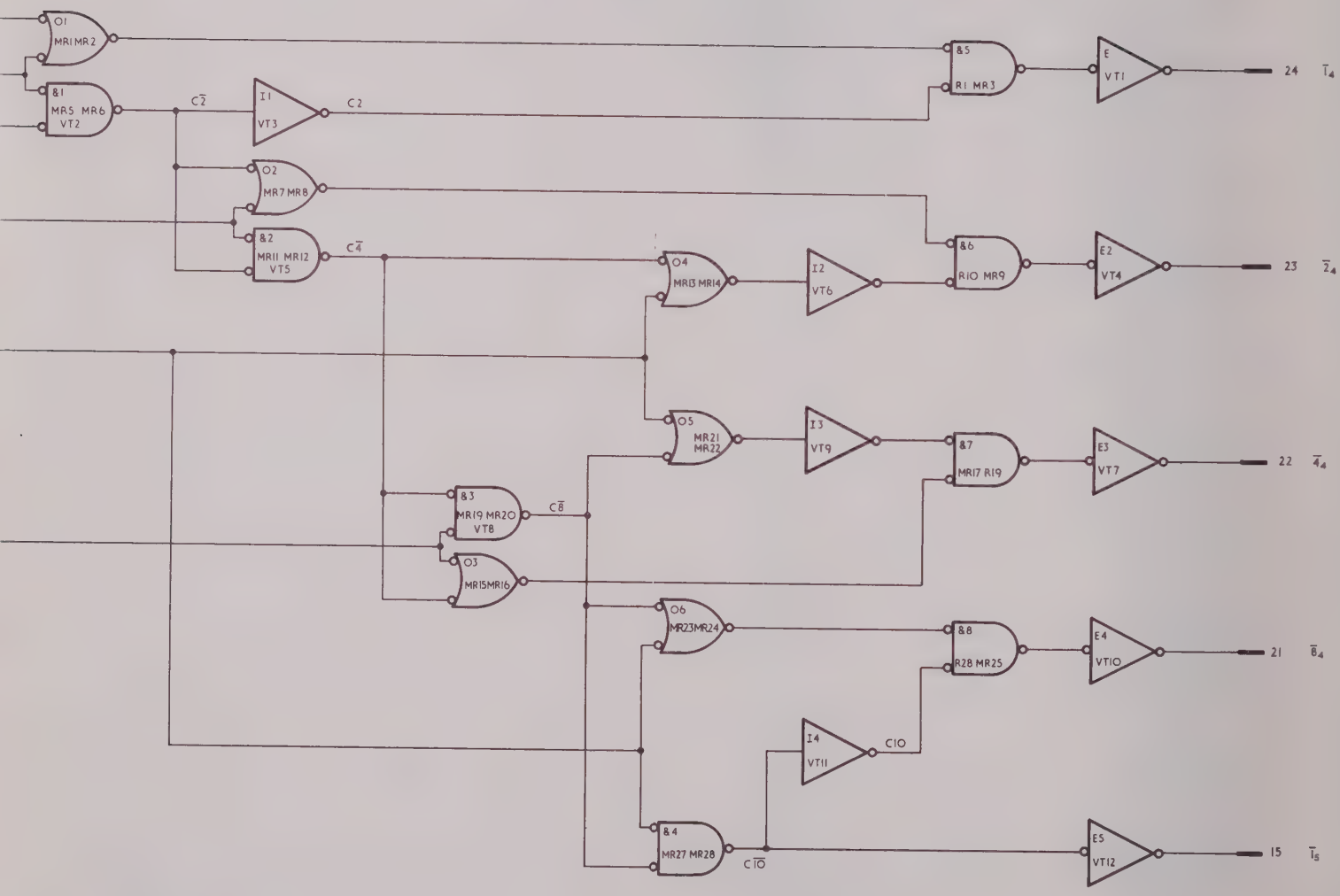
10^2 and Range Decade - Board No. 18699002



Logic Diagram 6

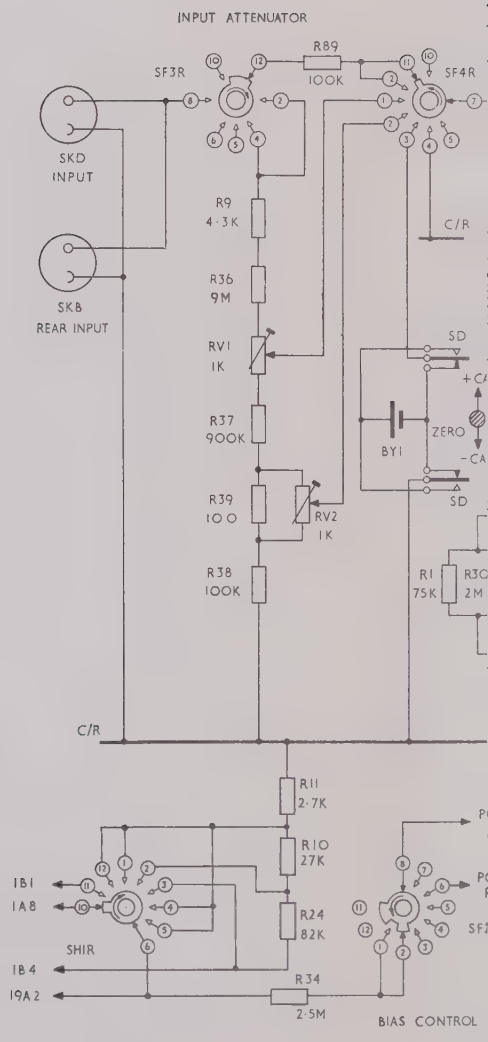
10^3 Decade - Board No. 18699003

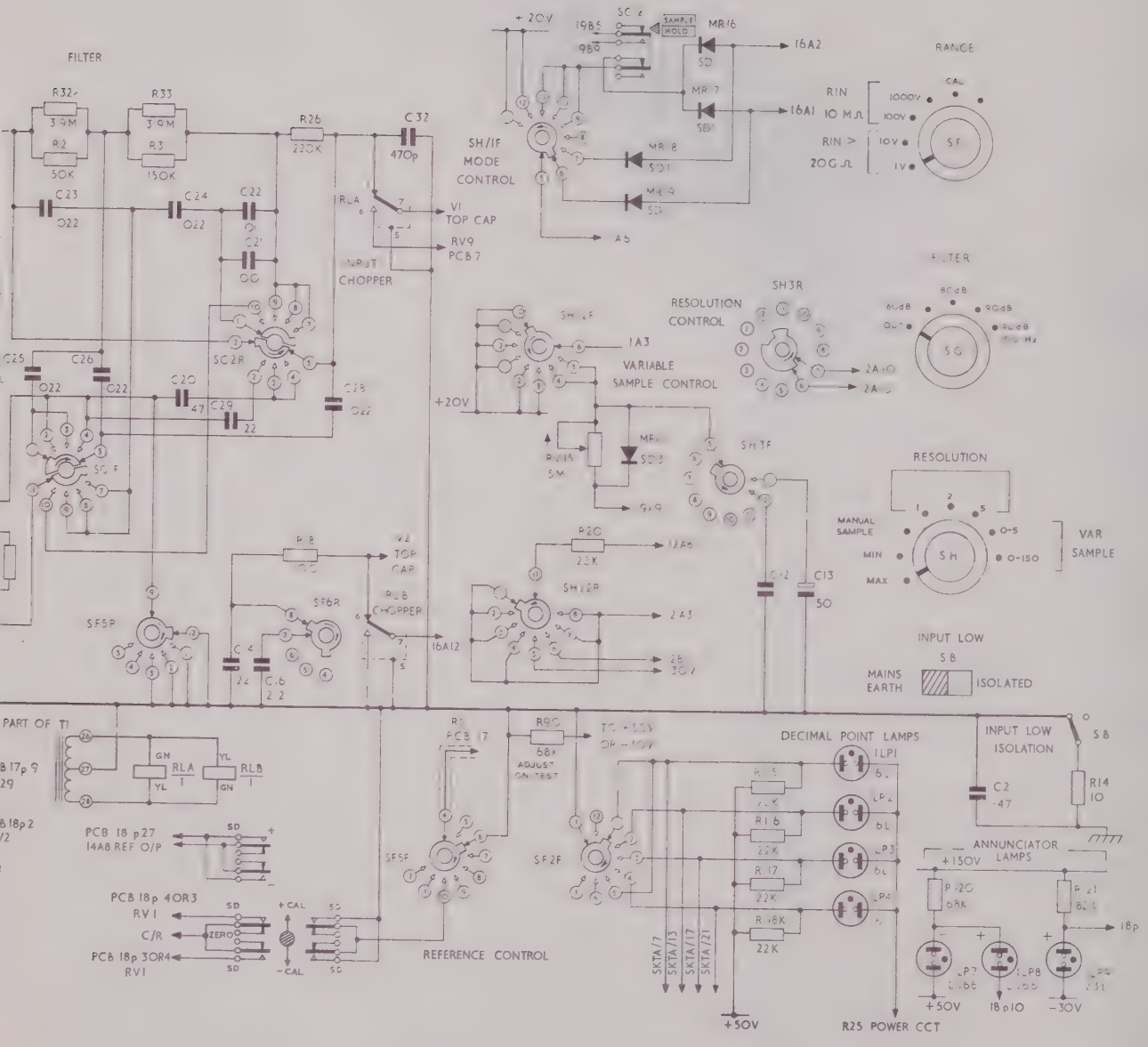
$C\bar{1}$
5
$\bar{T}_4$
7
$\bar{2}_4$
8
$\bar{2}_4'$
9
$\bar{4}$
10



Logic Diagram 7

10^4 and 10^5 Decades - Board No. 18699004

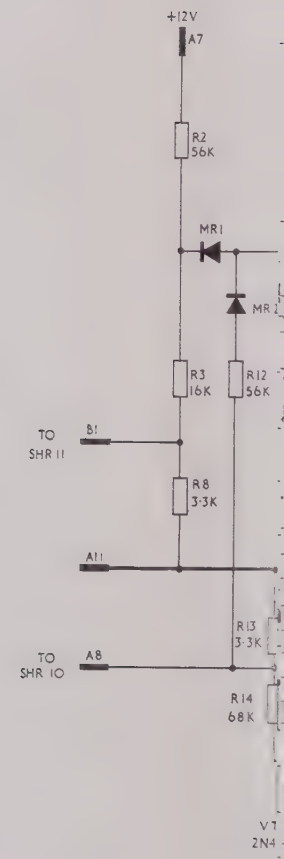

INPUT ATTENUATOR
R89
100K
SF3R
SF4R
SKD
INPUT
SKB
REAR INPUT
R9
4·3K
R36
9M
RV1
1K
R37
900K
R39
100
RV2
1K
R38
100K
C/R
SD
ZERO
BY1
R1
75K
R30
2M
R11
2·7K
R10
27K
R24
82K
1B1
1A8
SHIR
1B4
19A2
R34
2·5M
BIAS CONTROL

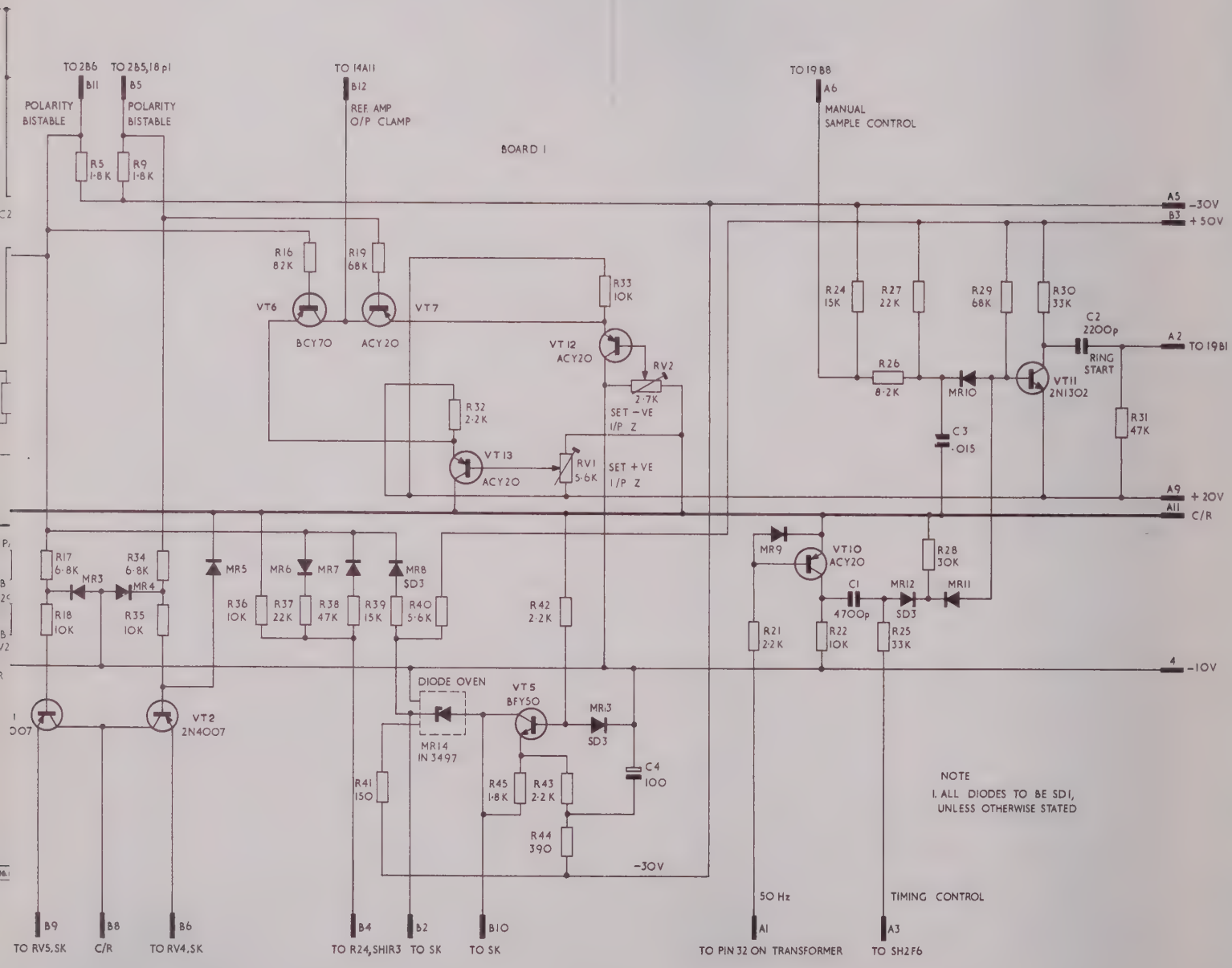


INPUT CIRCUIT & MODE CONTROL

DRAWING NUMBER

C18677001

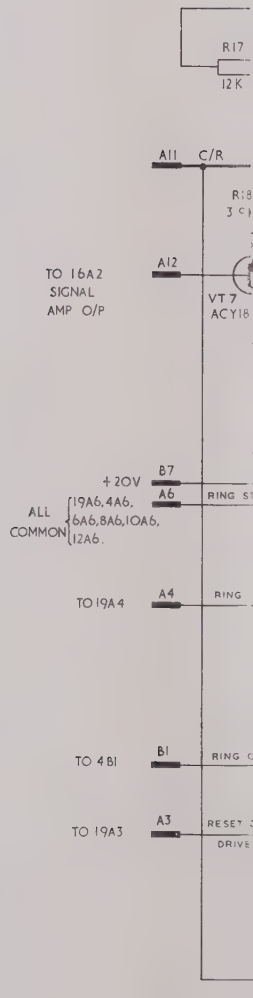

+12V
A7
R2
56K
MR1
MR2
R3
16K
R12
56K
TO
SHR 11
B1
R8
3·3K
A11
R13
3·3K
TO
SHR 10
A8
R14
68K
V7
2N4

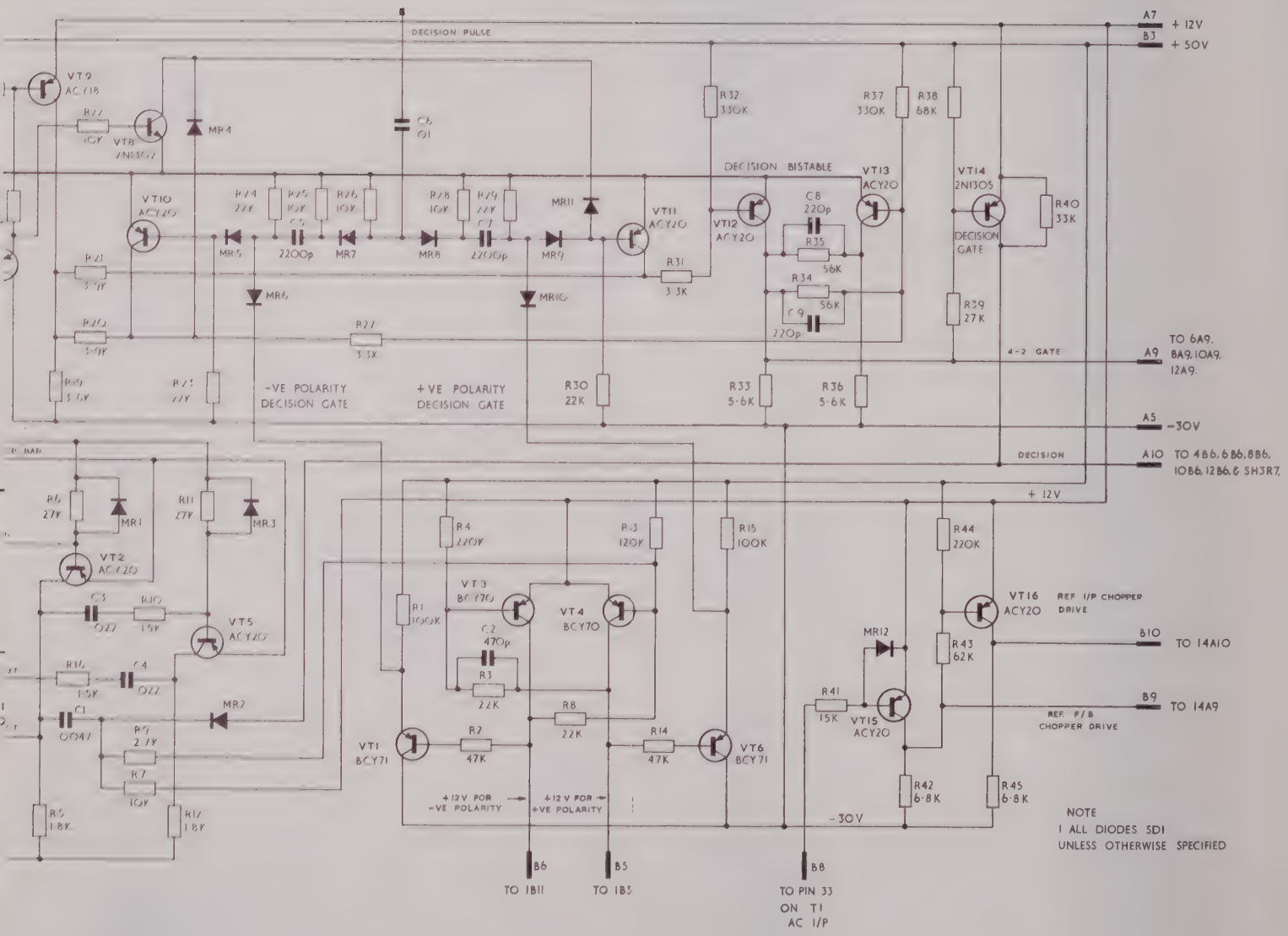


02A 30.4.69

BOARD 1 MODE CONTROL
POLARITY CONTROL & DECODE

DRAWING NUMBER
C 18679301

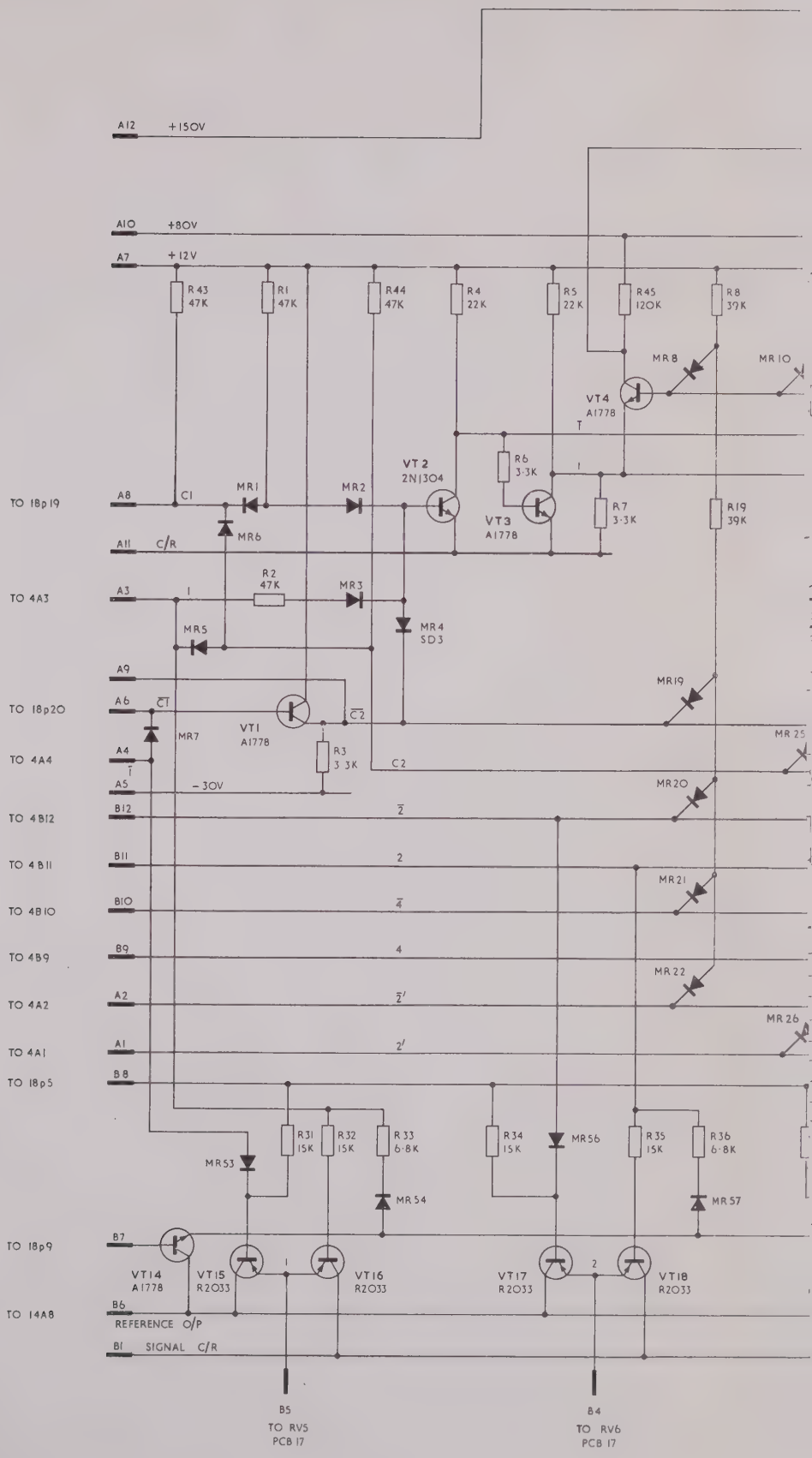

R17
12K
A11
C/R
A12
TO 16A2
SIGNAL
AMP O/P
VT 7
ACY18
+20V
B7
A6
ALL
COMMON
19A6, 4A6,
6A6, 8A6, 10A6,
12A6.
TO 19A4
A4
RING
TO 4B1
B1
TO 19A3
A3
RESET

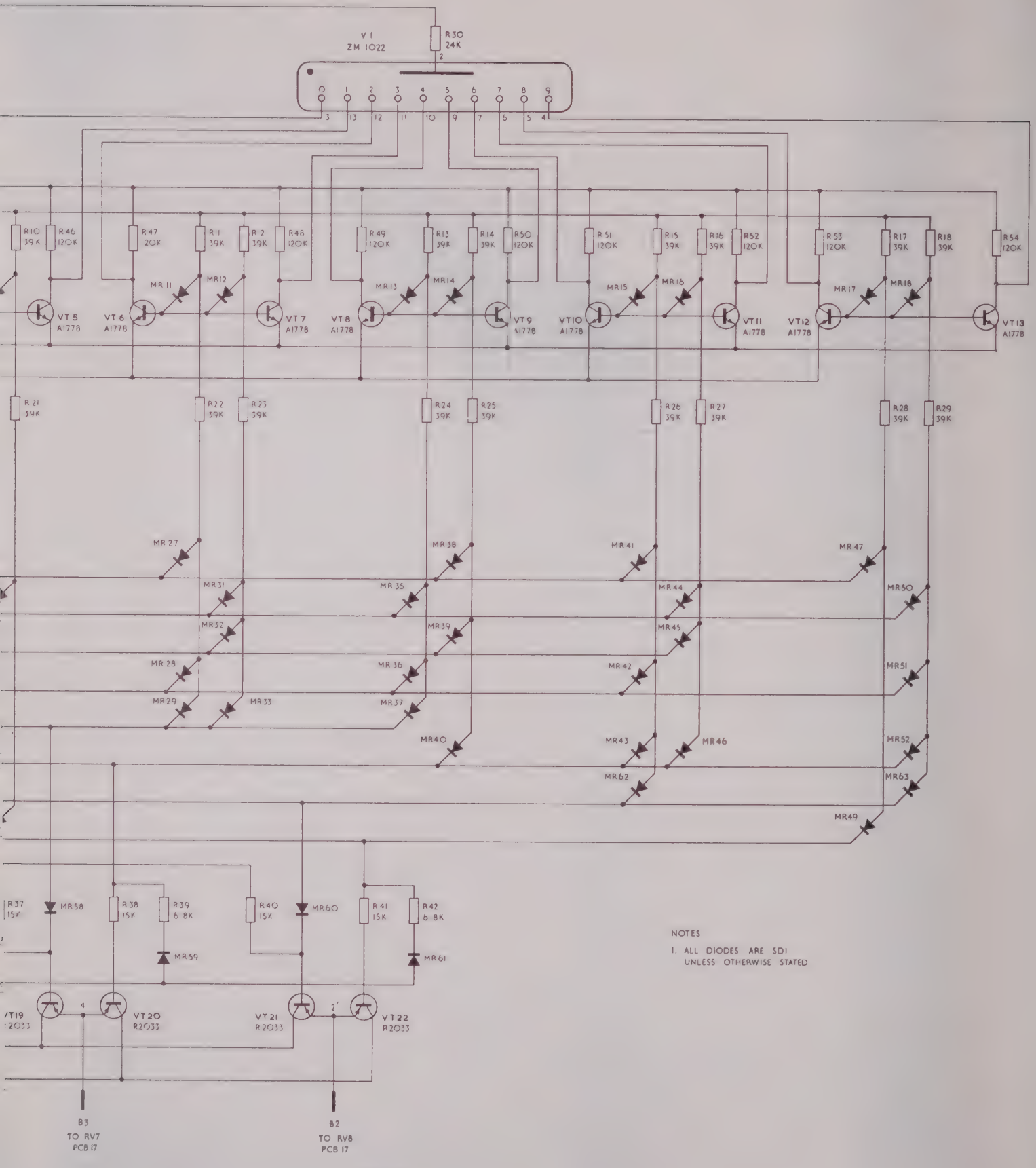


02A 24466

BOARD 2
DECISION & POLARITY CHOICE

DRAWING NUMBER
C18679302


A12 +150V
A10 +80V
A7 +12V
R43 47K
R1 47K
R44 47K
R4 22K
R5 22K
R45 120K
R8 39K
MR8
MR10
VT4 A1778
T
R6 3·3K
VT2 2N1304
VT3 A1778
R7 3·3K
R19 39K
TO 18p19
A8
C1
MR1
MR2
MR6
A11 C/R
TO 4A3
A3
1
R2 47K
MR3
MR4 SD3
MR5
A9
MR19
TO 18p20
A6
C1
C2
VT1 A1778
MR7
MR25
TO 4A4
A4
1
R3 3·3K
C2
A5 −30V
MR20
TO 4B12
B12
2
TO 4B11
B11
2
MR21
TO 4B10
B10
4
TO 4B9
B9
4
MR22
TO 4A2
A2
2'
MR26
TO 4A1
A1
2'
TO 18p5
B8
R31 15K
R32 15K
R33 6·8K
R34 15K
MR56
R35 15K
R36 6·8K
MR53
MR54
MR57
TO 18p9
B7
VT14 A1778
VT15 R2033
VT16 R2033
VT17 R2033
VT18 R2033
TO 14A8
B6
REFERENCE O/P
B1 SIGNAL C/R
B5
TO RV5
PCB 17
B4
TO RV6
PCB 17



NOTES

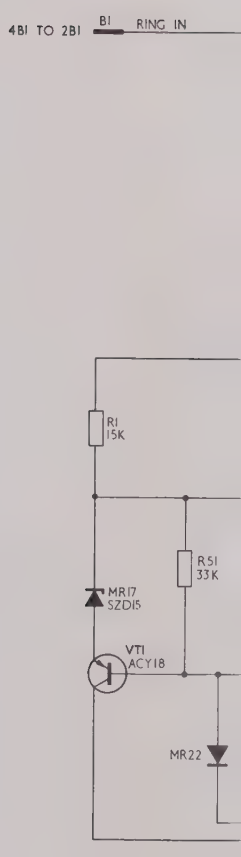
1. ALL DIODES ARE SD1 UNLESS OTHERWISE STATED

02/A28.4.69

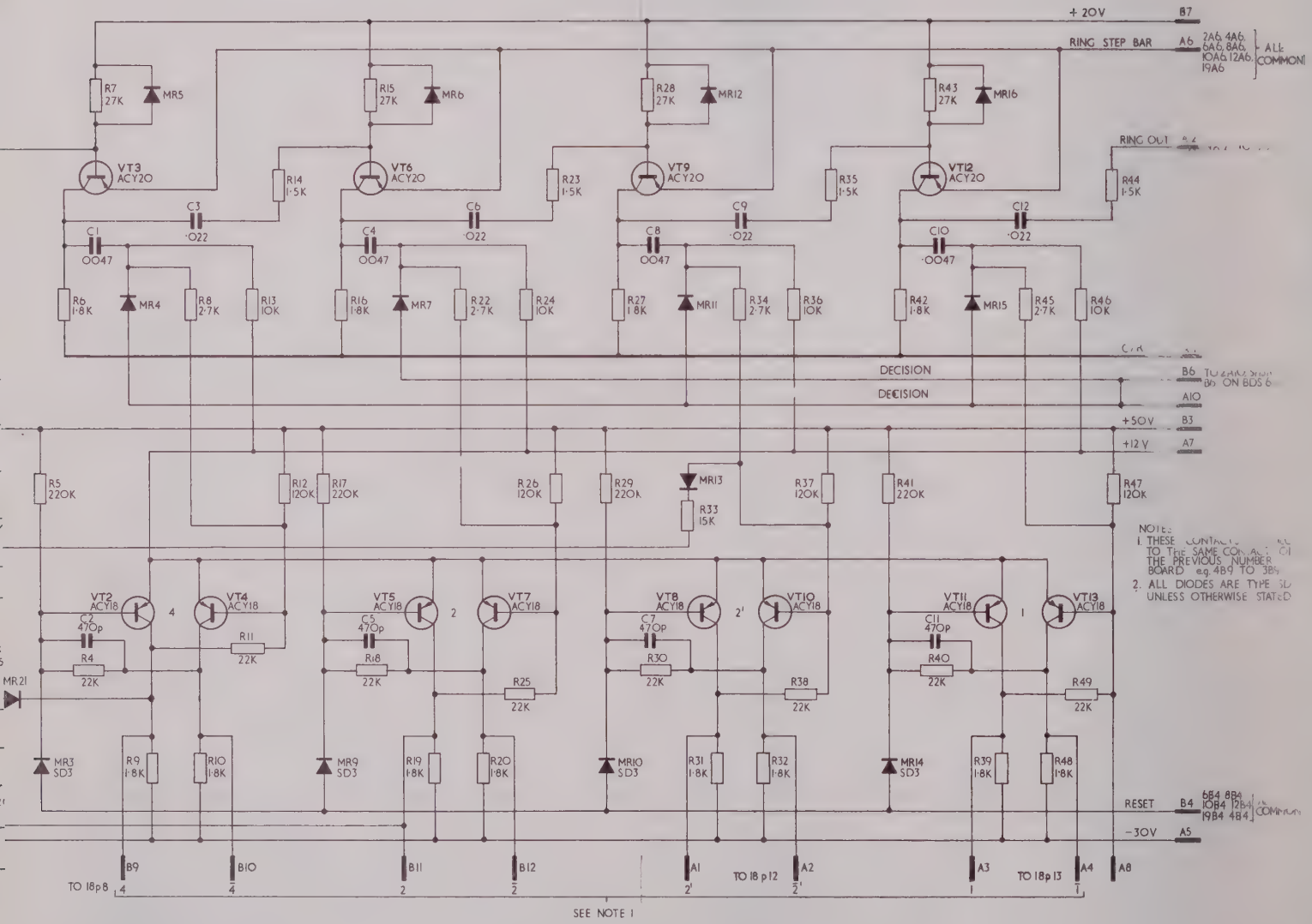
P.C. BOARD 3 DECADE & EMITTER SWITCHES.

DRAWING NUMBER

D 18679303

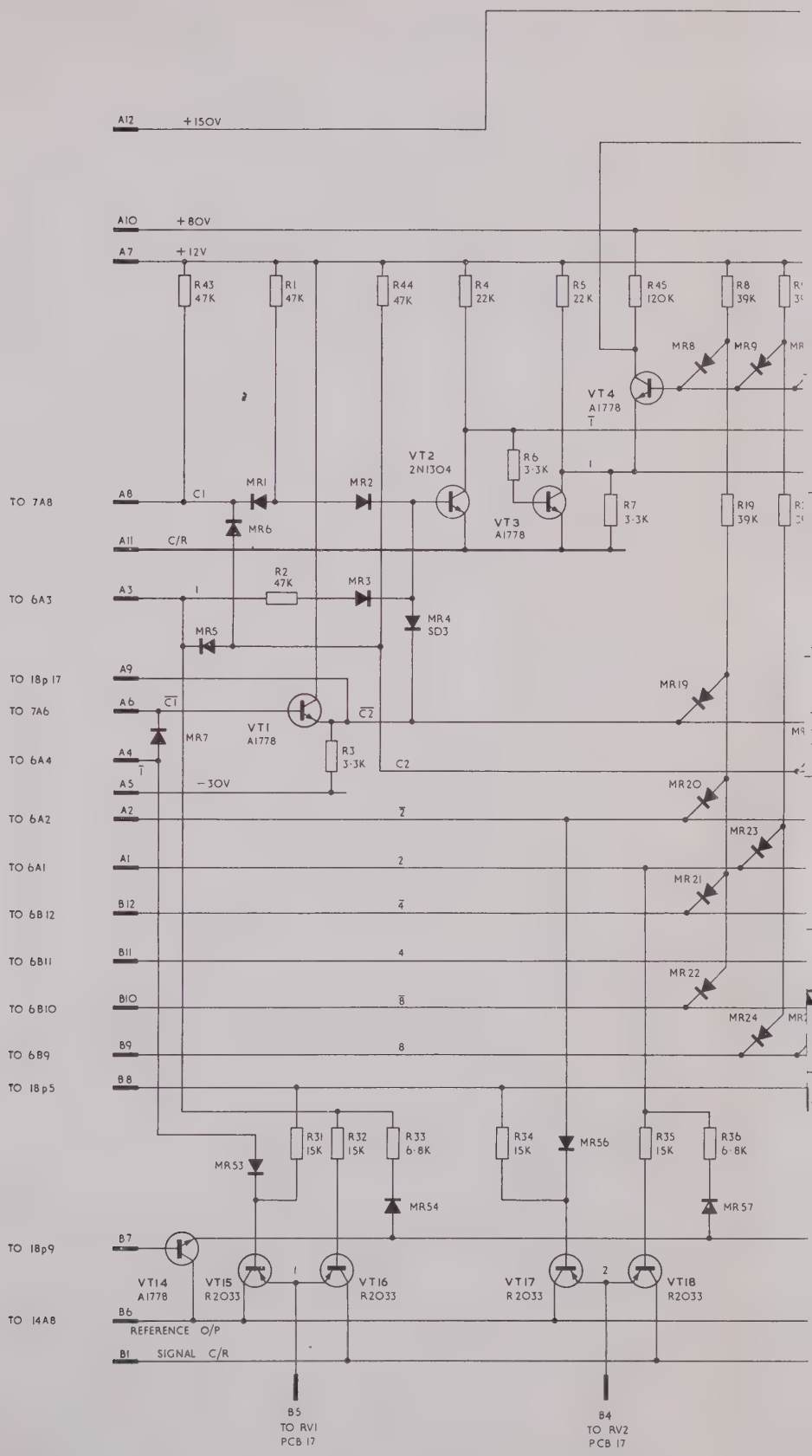


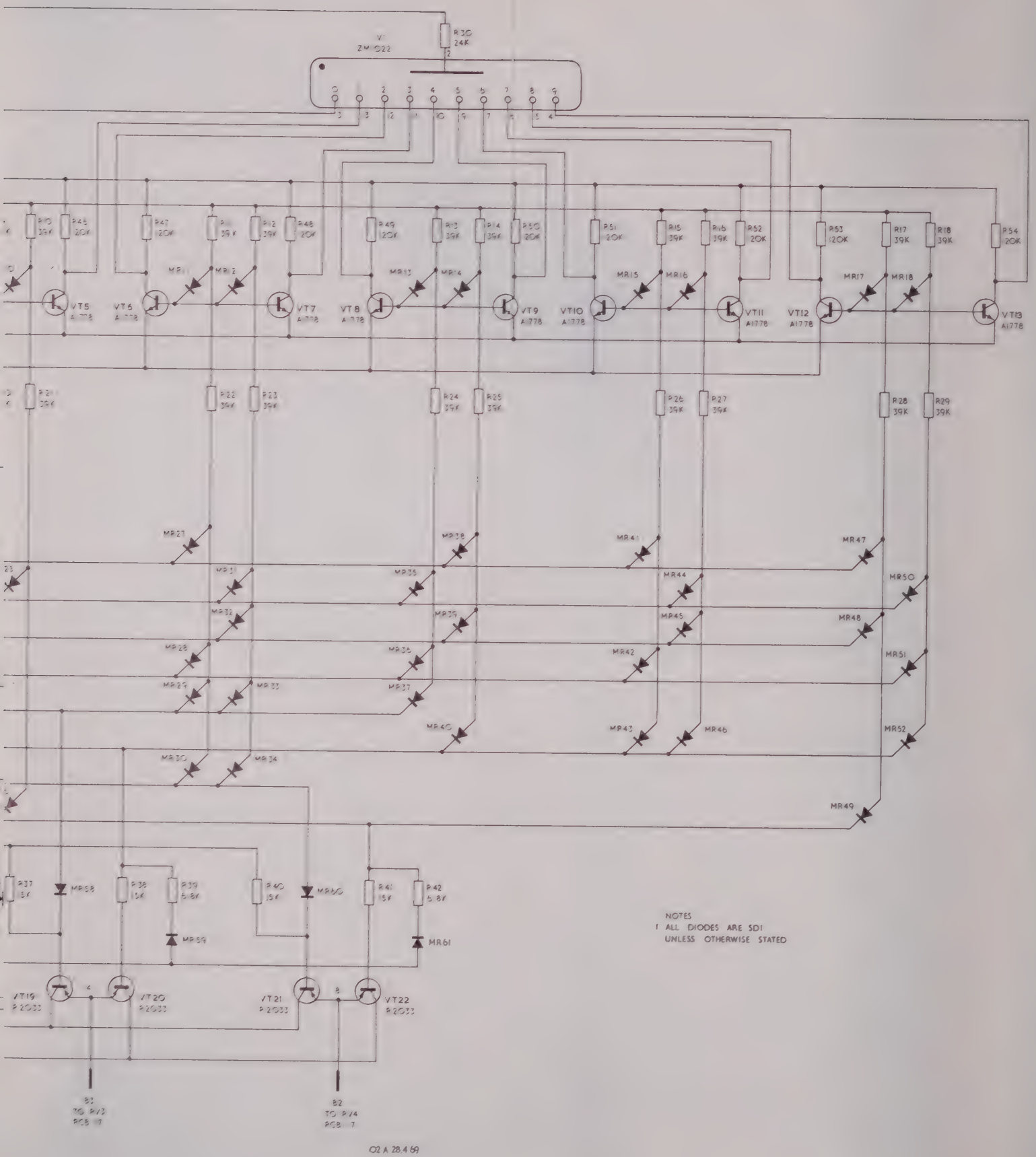
22A 24469



BOARD 4
DECADE RING & BISTABLE (TEN THOUSANDS)

DRAWING NUMBER
C18679304


A12 +150V
A10 +80V
A7 +12V
R43 47K
R1 47K
R44 47K
R4 22K
R5 22K
R45 120K
R8 39K
MR8
MR9
VT4 A1778
VT2 2N1304
R6 3·3K
VT3 A1778
R7 3·3K
R19 39K
TO 7A8
A8
C1
MR1
MR2
MR6
A11 C/R
TO 6A3
A3
R2 47K
MR3
MR4 SD3
MR5
TO 18p17
A9
TO 7A6
A6
VT1 A1778
MR7
TO 6A4
A4
R3 3·3K
C2
A5 −30V
MR19
MR20
TO 6A2
A2
MR23
TO 6A1
A1
MR21
TO 6B12
B12
TO 6B11
B11
MR22
TO 6B10
B10
MR24
TO 6B9
B9
TO 6B8
B8
TO 18p5
R31 15K
R32 15K
R33 6·8K
R34 15K
MR56
R35 15K
R36 6·8K
MR53
MR54
MR57
TO 18p9
B7
VT14 A1778
VT15 R2033
VT16 R2033
VT17 R2033
VT18 R2033
TO 14A8
B6
REFERENCE O/P
B1 SIGNAL C/R
B5 TO RV1 PCB 17
B4 TO RV2 PCB 17

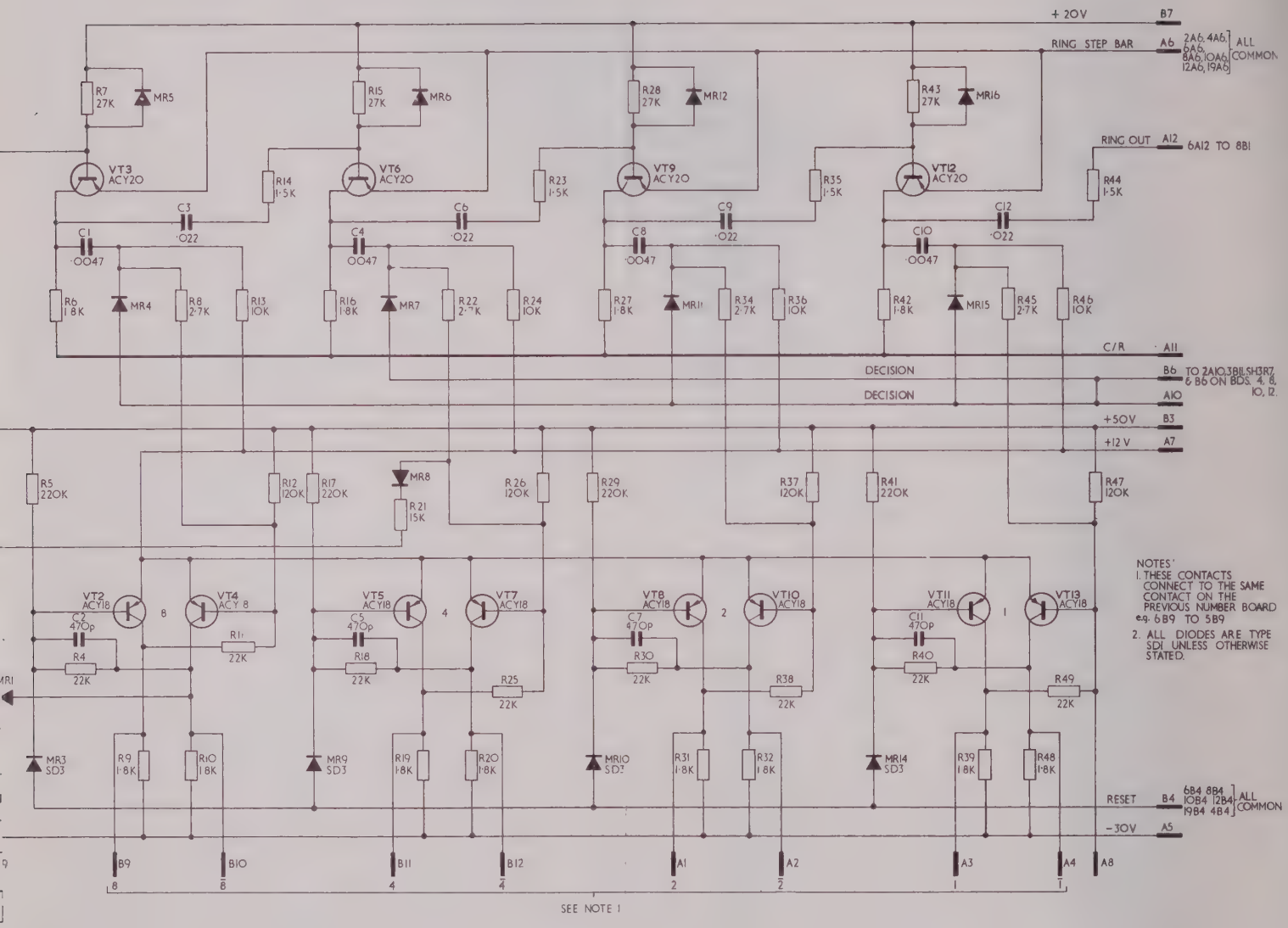


NOTES
1 ALL DIODES ARE SD1
UNLESS OTHERWISE STATED

02 A 28.4.69

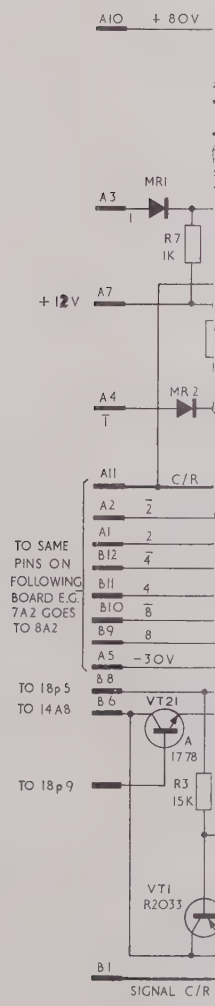
P.C. BOARD 5 DECADE & EMITTER SWITCHES.

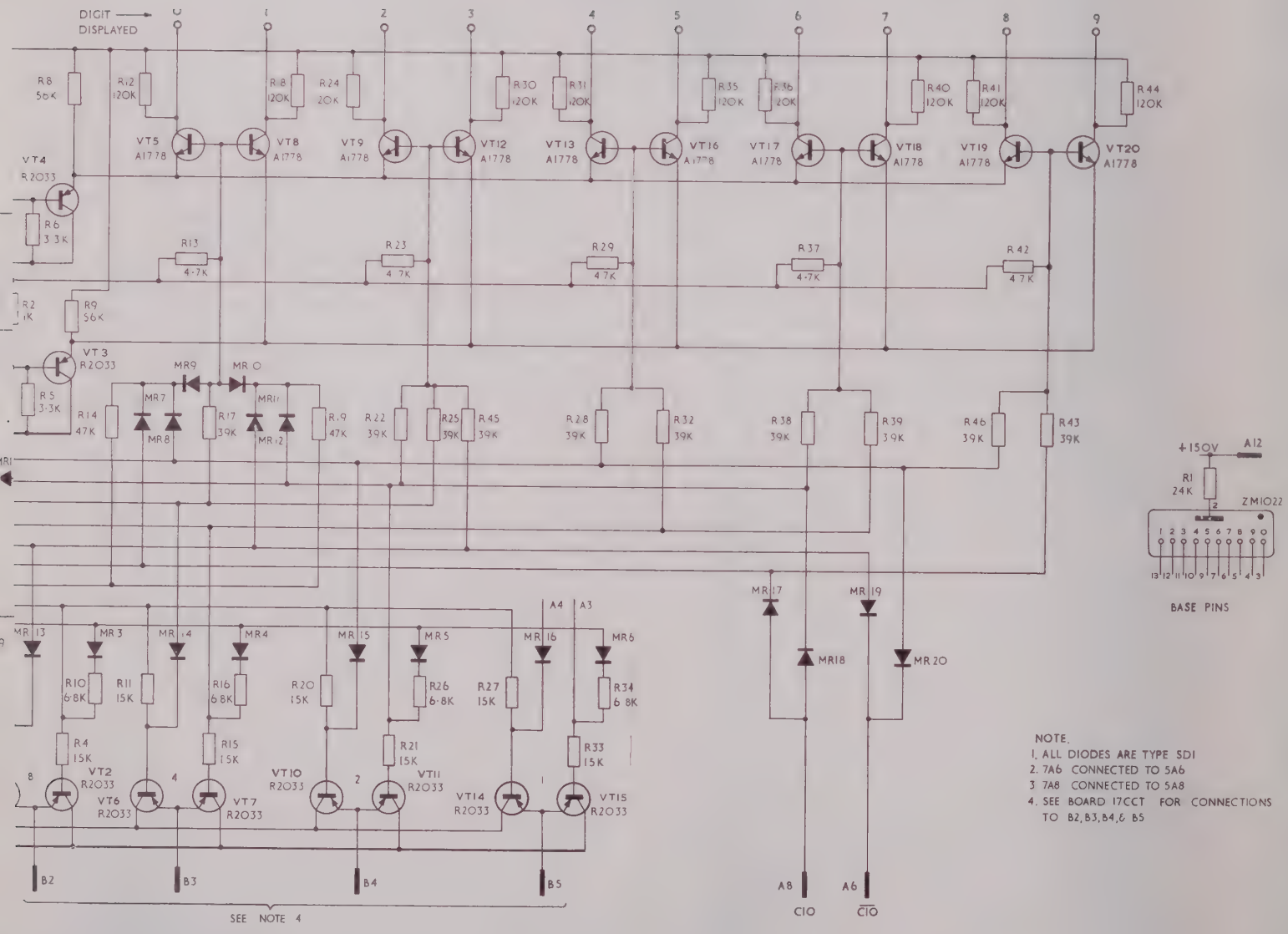
DRAWING NUMBER
D 18679305



BOARD 6
DECADE RING & BISTABLE (THOUSANDS)

DRAWING NUMBER
C18679306


A10 + 80V
MR1
A3
1
R7
1K
+12V
A7
MR2
A4
T
A11
C/R
A2
2
A1
4
B12
8
B11
B10
B9
A5 -30V
B8
TO SAME PINS ON FOLLOWING BOARD E.G. 7A2 GOES TO 8A2
TO 18p5
TO 14A8
B6
VT21
A 1778
TO 18p9
R3 15K
VT1 R2033
B1
SIGNAL C/R

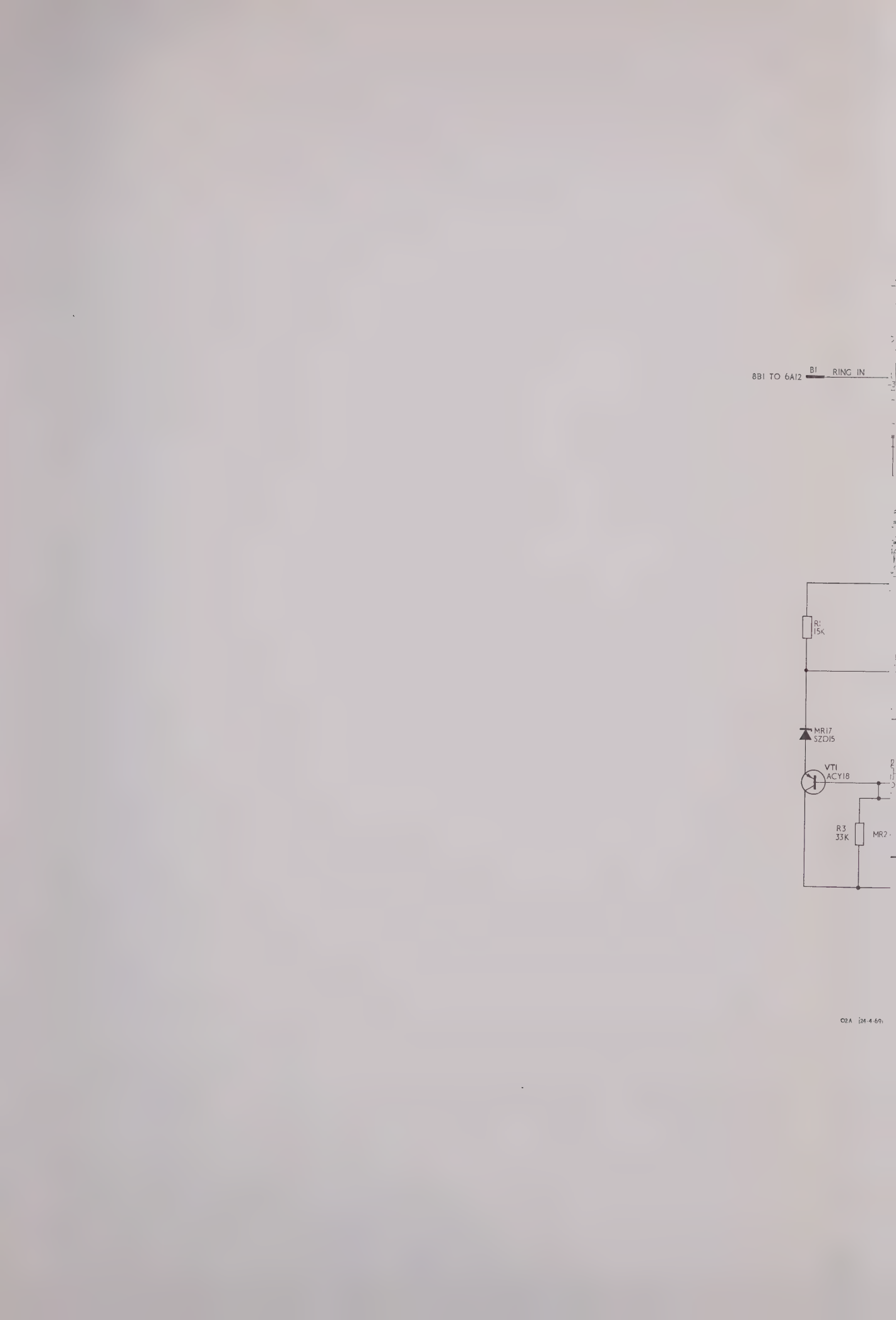


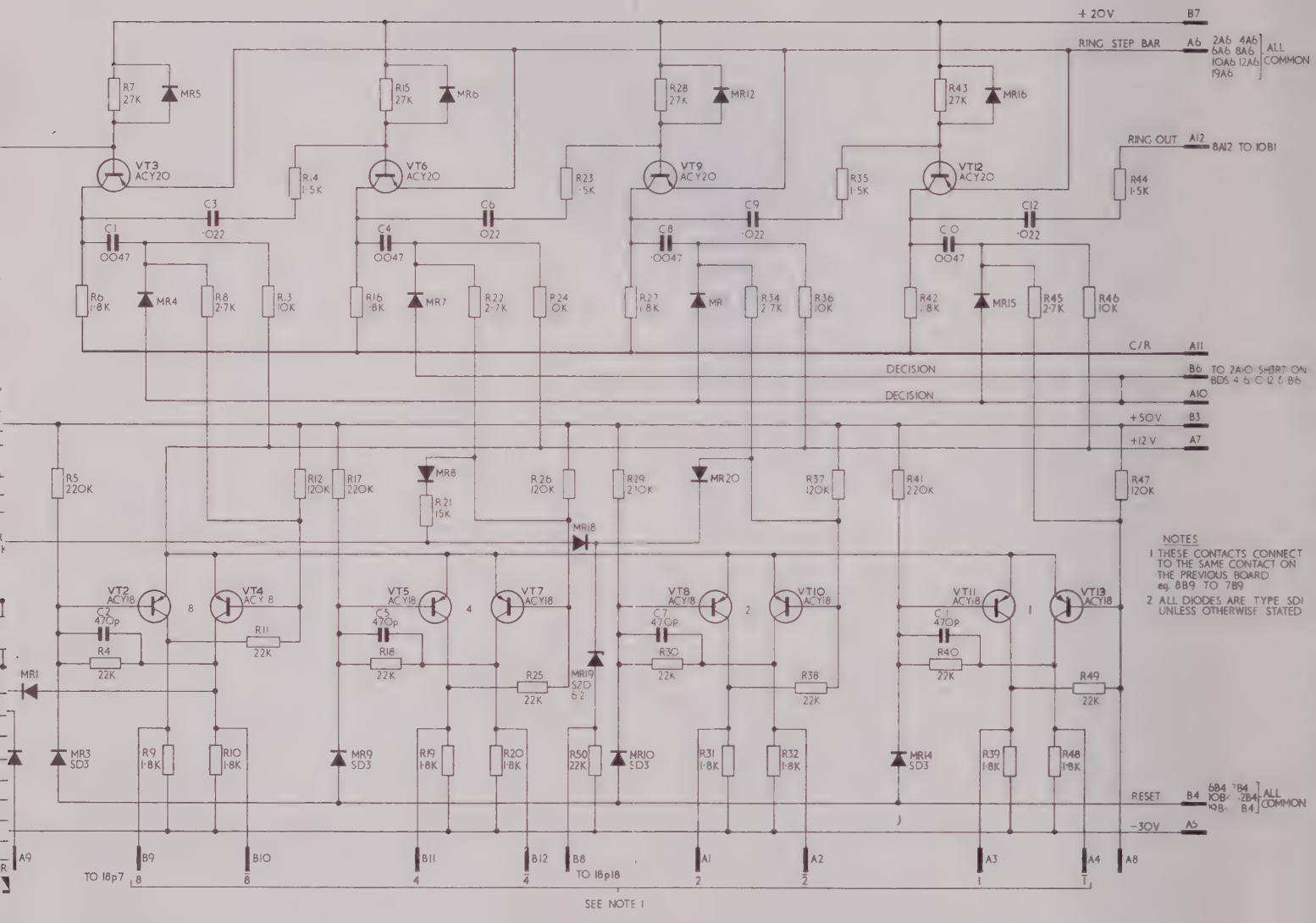
NOTE.
1. ALL DIODES ARE TYPE SD1
2. 7A6 CONNECTED TO 5A6
3. 7A8 CONNECTED TO 5A8
4. SEE BOARD 17CCT FOR CONNECTIONS TO B2, B3, B4, & B5

A 1-5 69

BOARDS 7, 9 & 11 DECODE & EMITTER SWITCHES

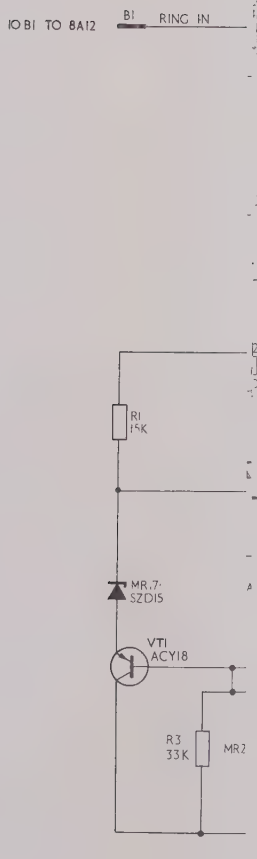
DRAWING NUMBER
C18679307

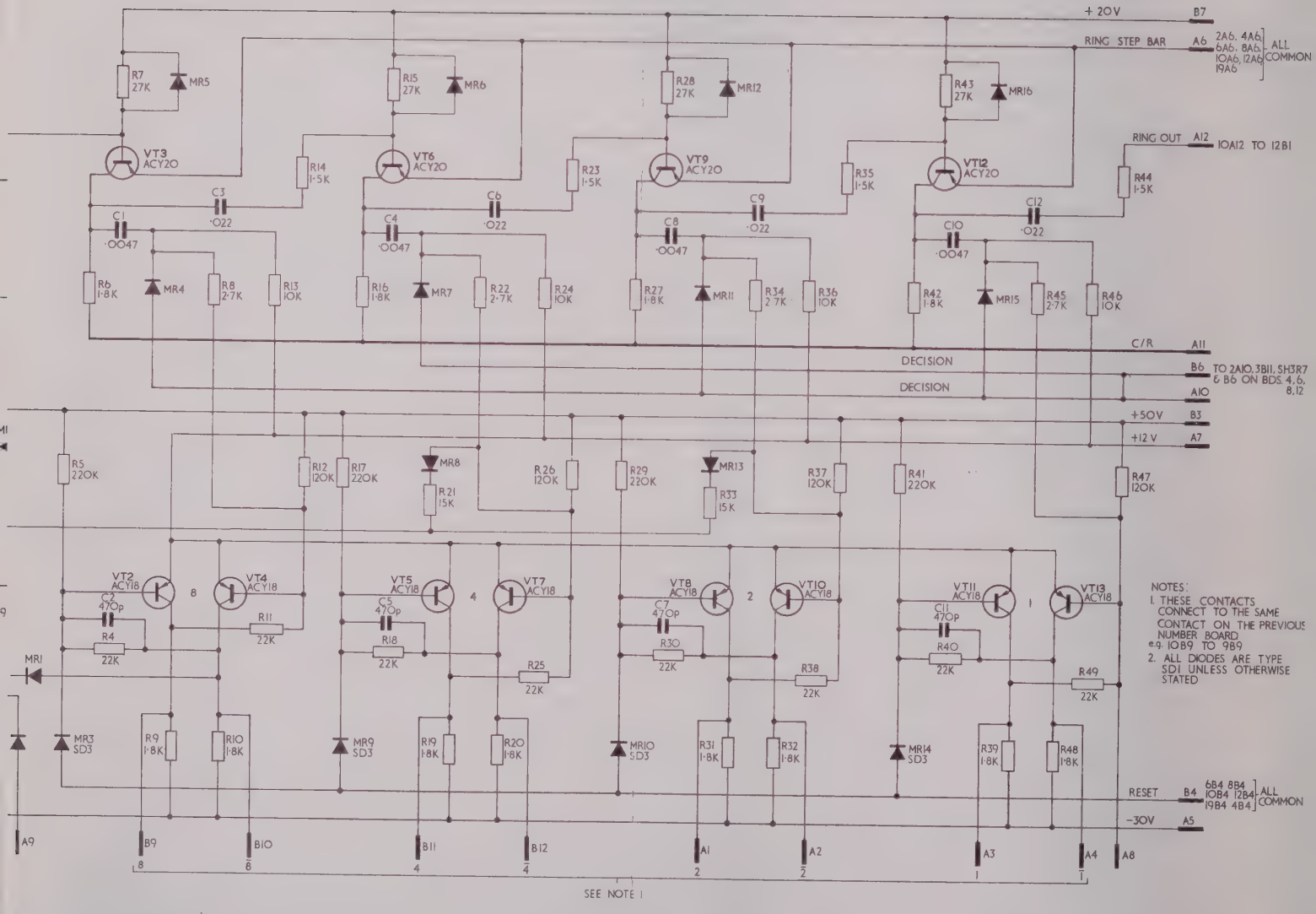

8B1 TO 6A12
B1
RING IN
R1
15K
MR17
SZD15
VT1
ACY18
R3
33K
MR2



BOARD 8
DECADE RING & BISTABLE (HUNDREDS)

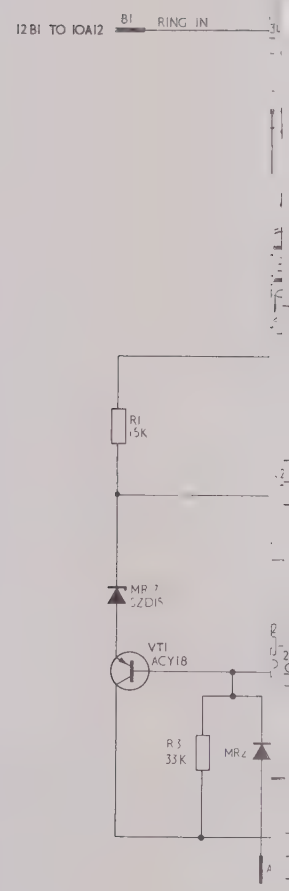
DRAWING NUMBER
C18679308


10 B1 TO 8A12
B1
RING IN
R1
1·5K
MR.7·
SZDIS
VT1
ACY18
R3
33K
MR2

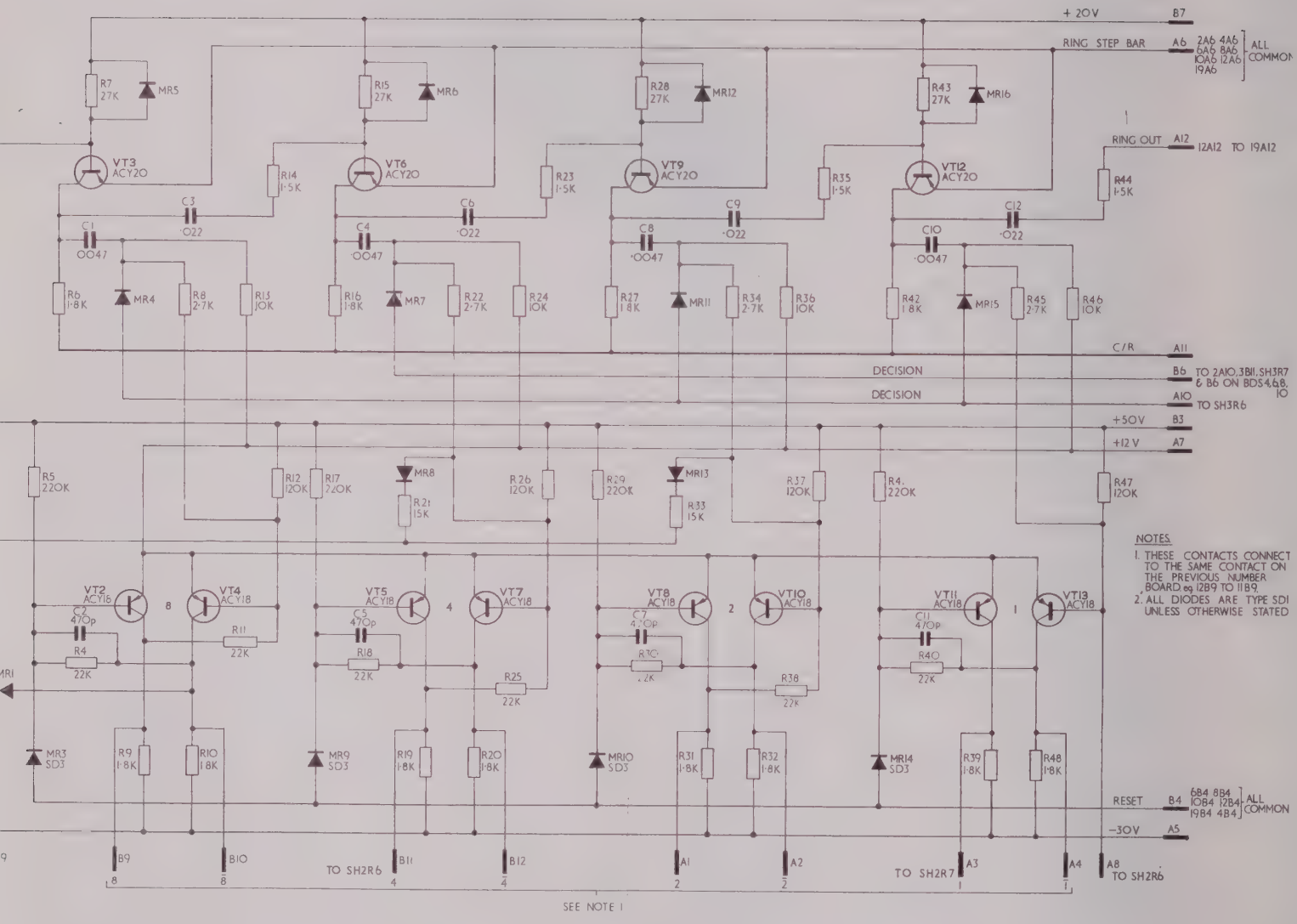


BOARD 10
DECADE RING & BISTABLE (TENS)

DRAWING NUMBER
C18679310

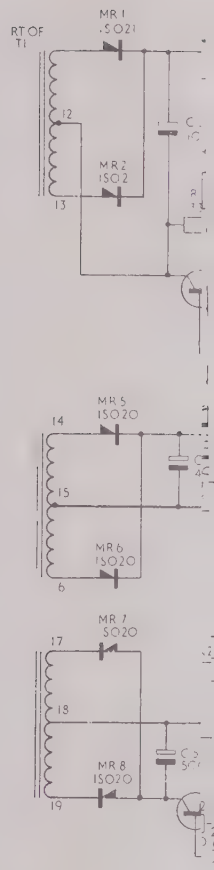


02A 24469

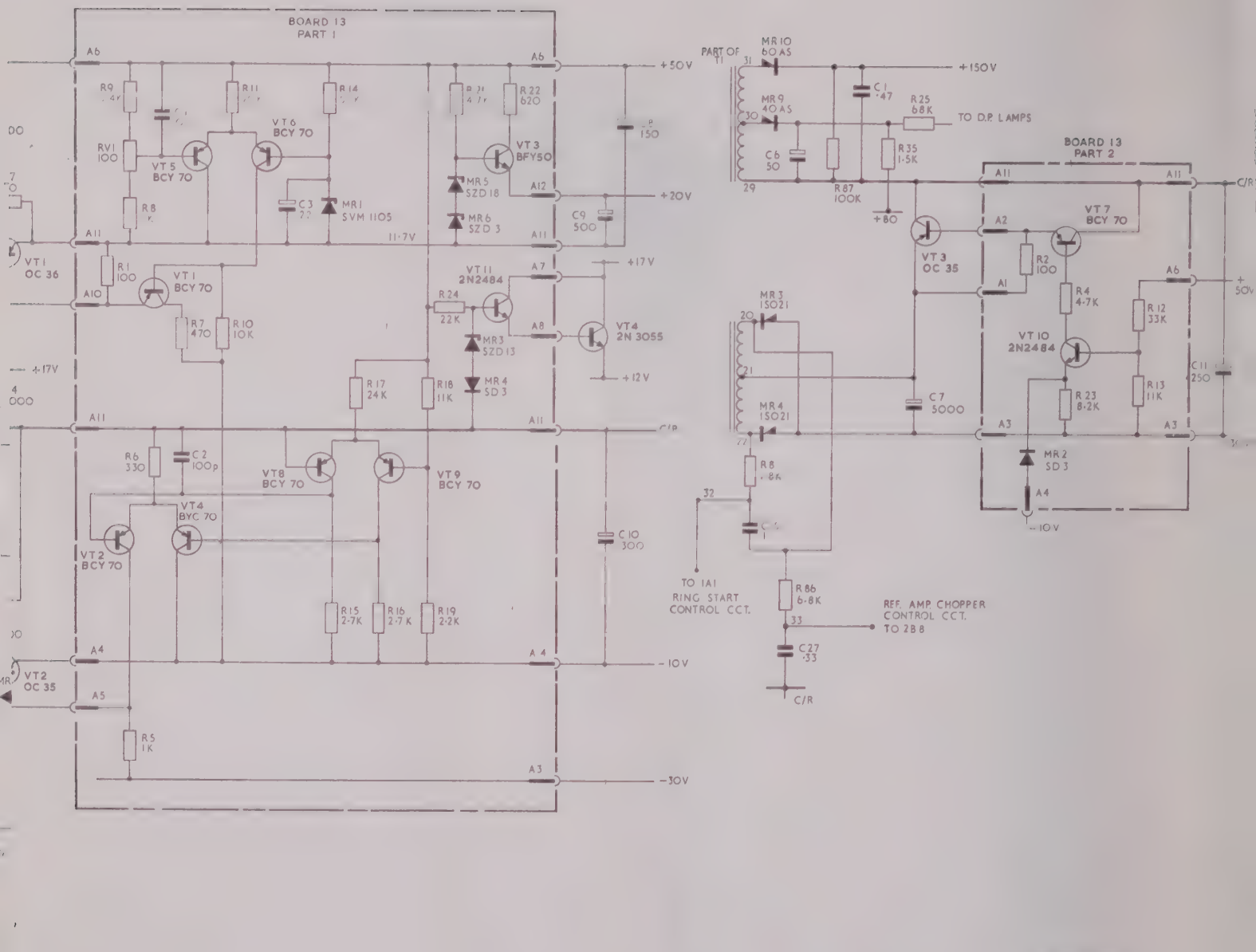


BOARD 12
DECADE RING & BISTABLE (UNITS)

DRAWING NUMBER
C18679312

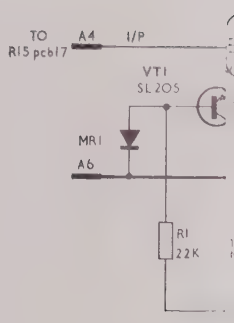

RT OF T1
MR1 1SO21
12
13
MR2 1SO2
MR5 1SO20
14
15
MR6 1SO20
6
MR7 SO20
17
18
MR8 1SO20
19

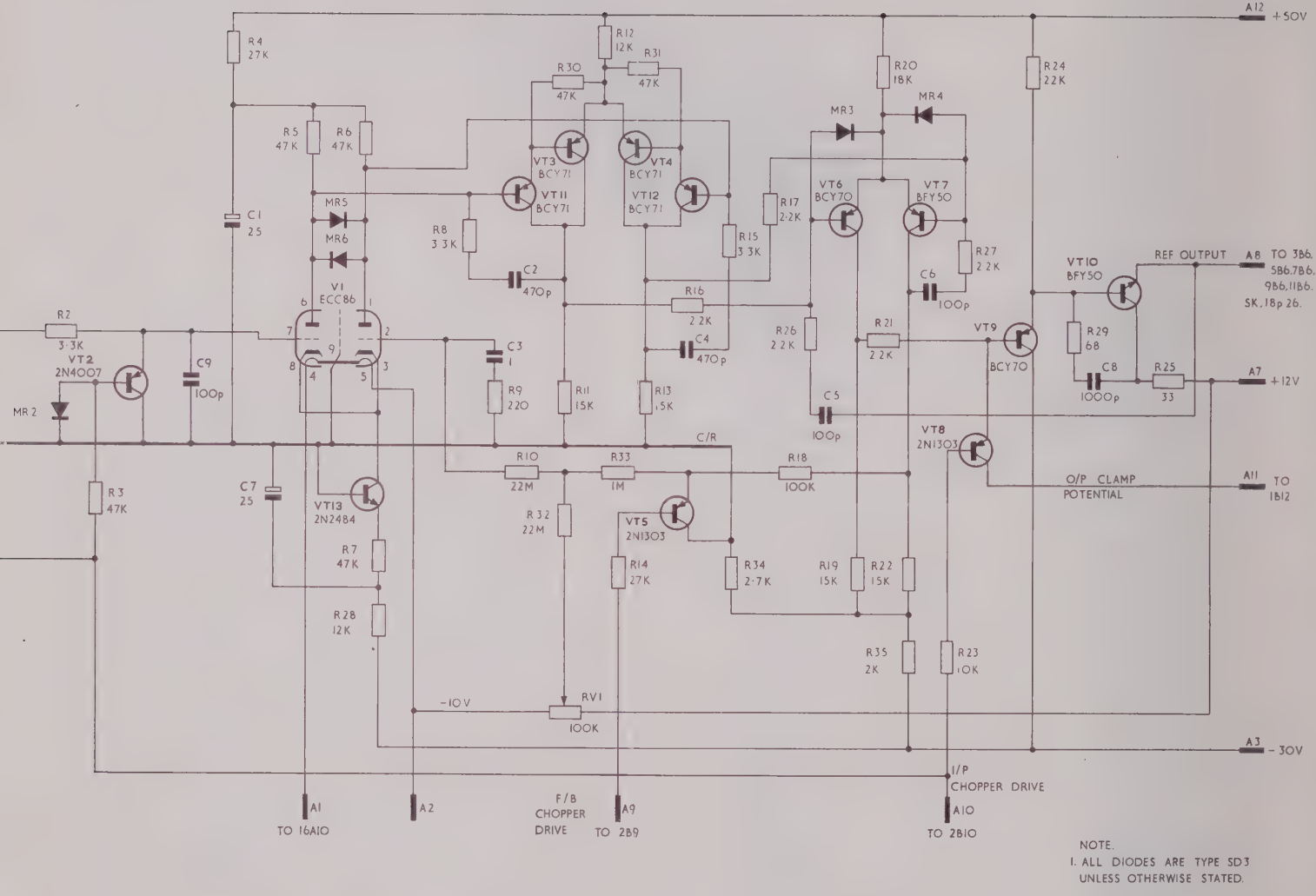
02A 29-48



BOARD 13 POWER SUPPLY

DRAWING NUMBER
C 18679313

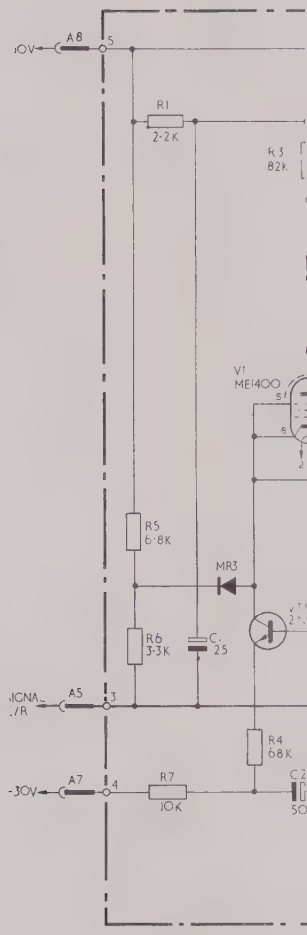

TO
R15 pcb17
A4
I/P
VT1
SL 205
MR1
A6
R1
22K



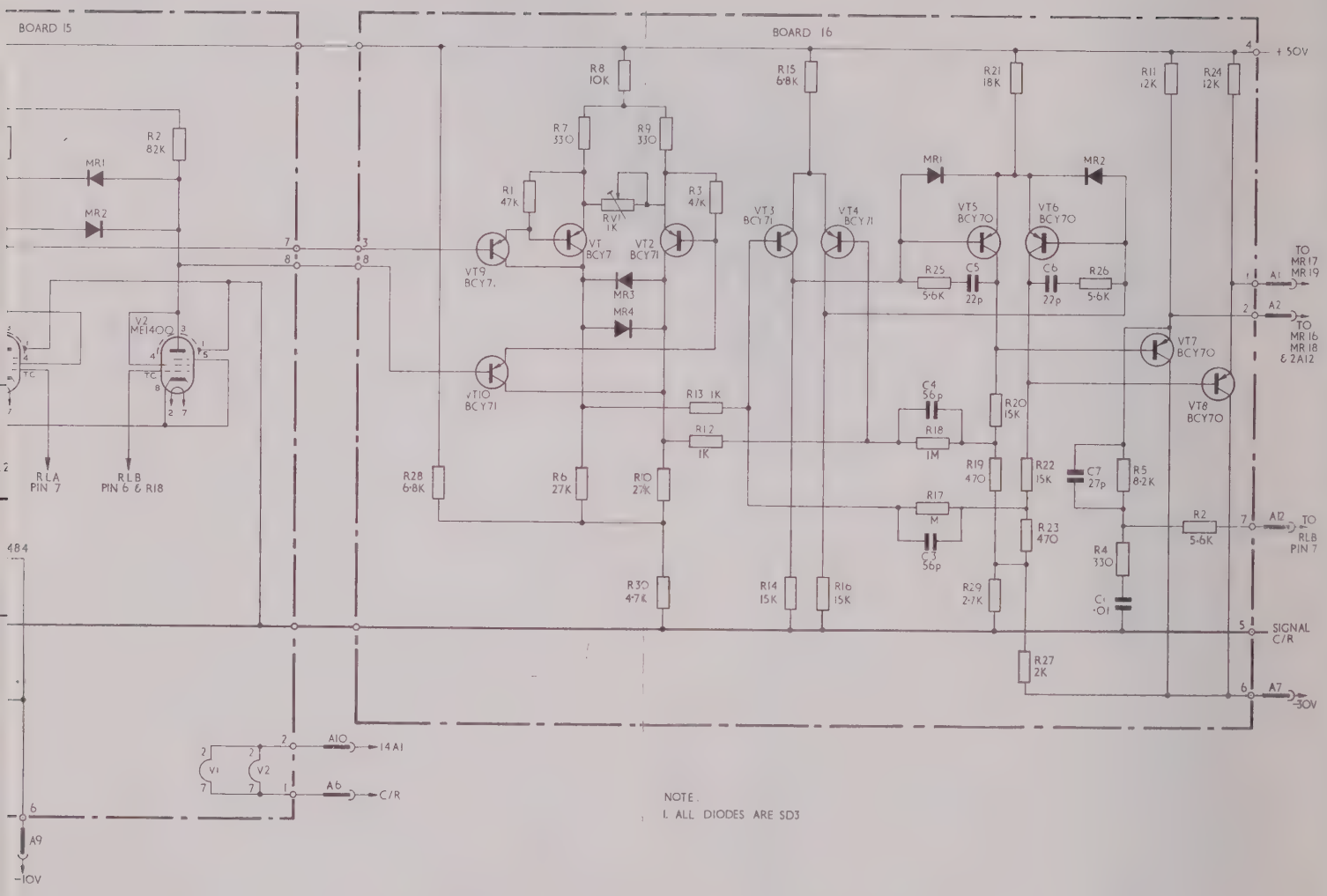
NOTE.
1. ALL DIODES ARE TYPE SD3 UNLESS OTHERWISE STATED.

BOARD 14
REFERENCE AMPLIFIER

DRAWING NUMBER
C 18679314


A8
5
R1
2·2K
R3
82k
V1
ME1400
R5
6·8K
MR3
R6
3·3K
C
25
A5
3
R4
68K
A7
4
R7
10K

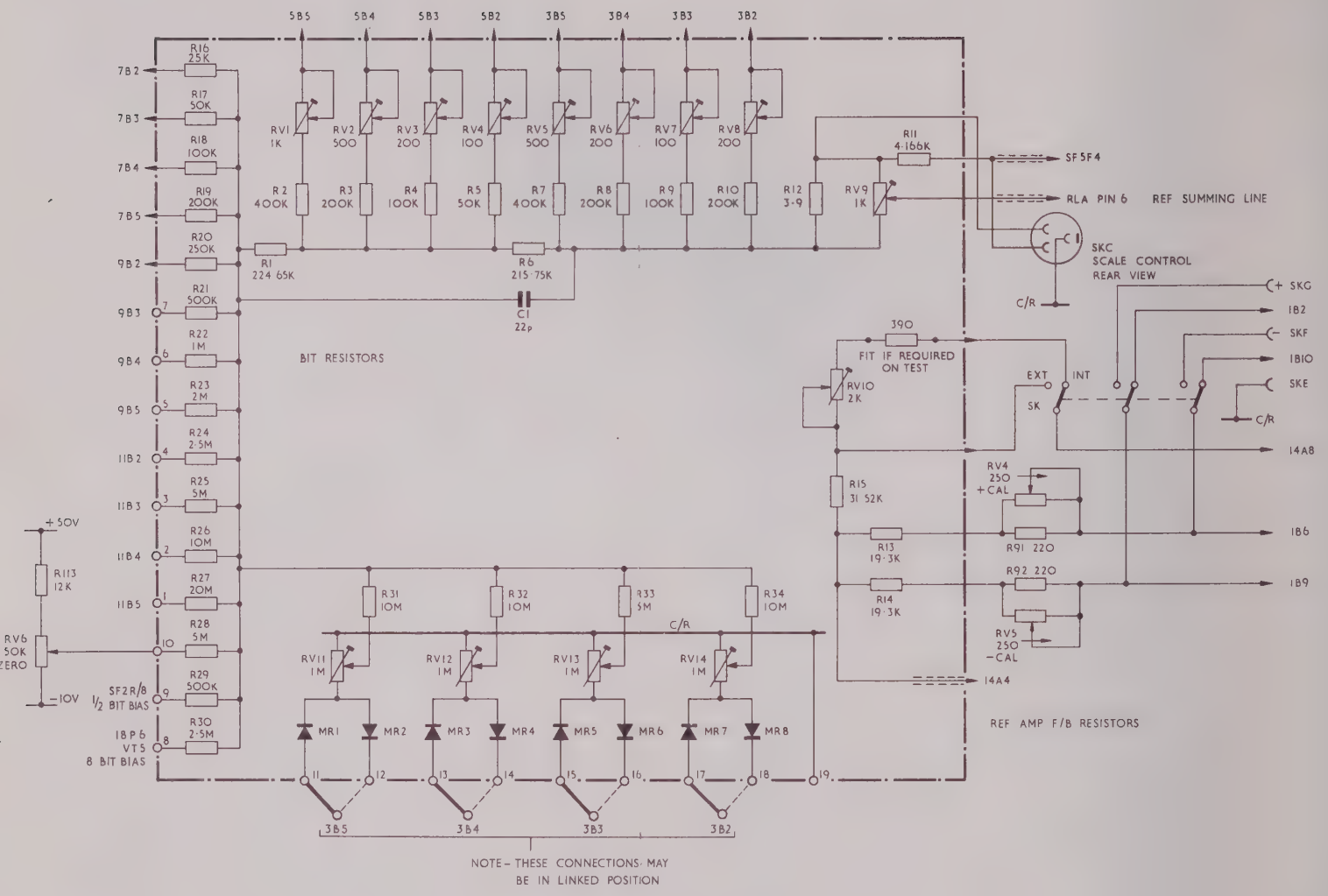
01A 24·4·69



INPUT AMPLIFIER. P.C. BOARDS 15 & 16

DRAWING NUMBER

C18679315



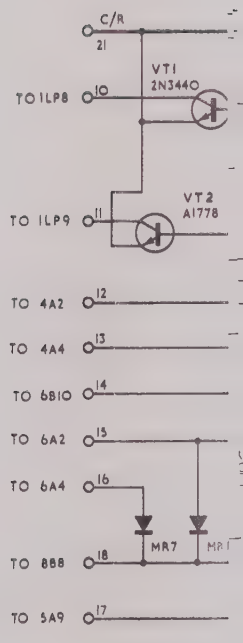
NOTE – THESE CONNECTIONS MAY BE IN LINKED POSITION

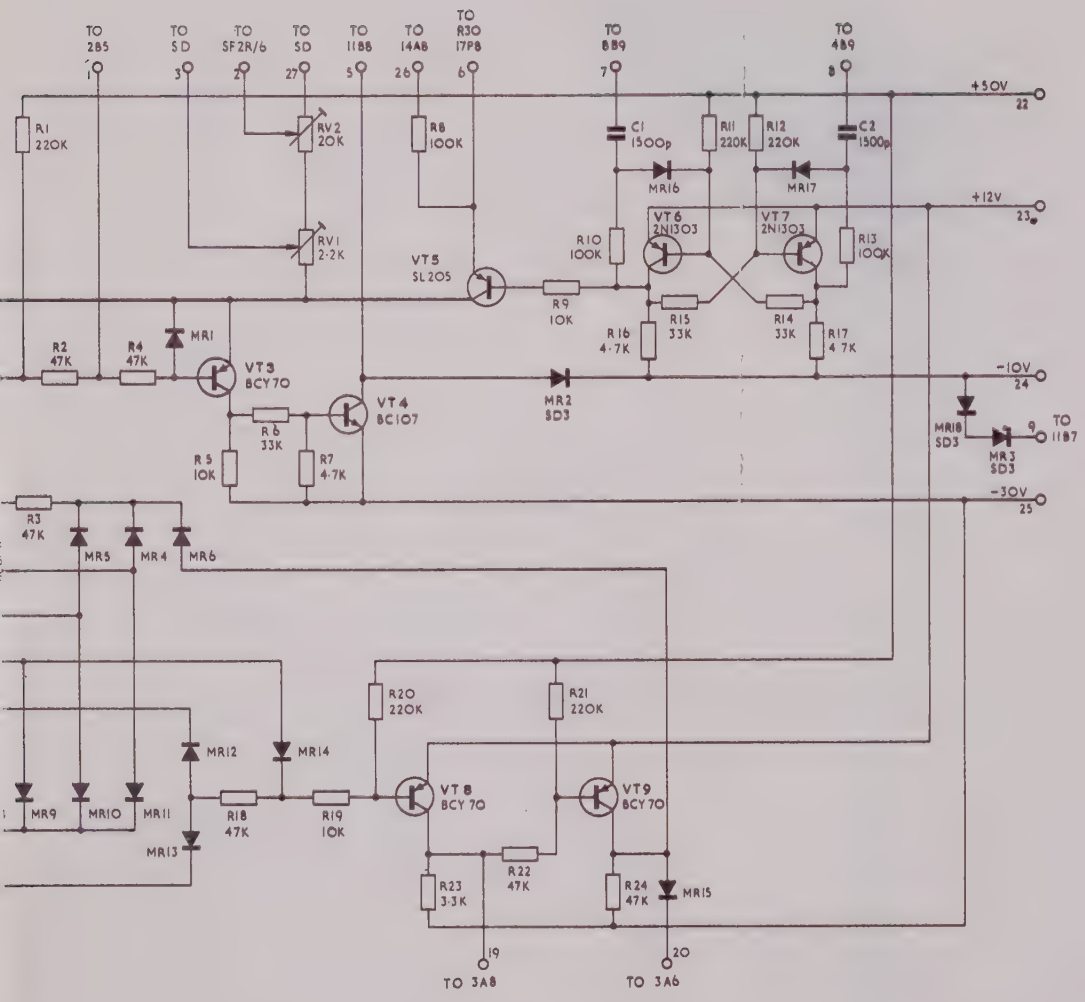
02 A 28.4.69

DRAWING NUMBER

REFERENCE RESISTOR P.C.B. 17

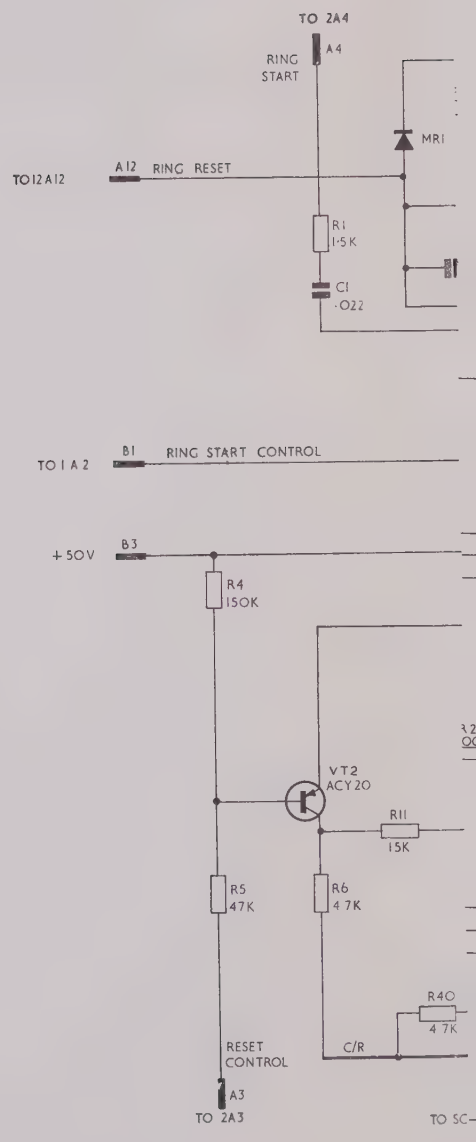
C18679317

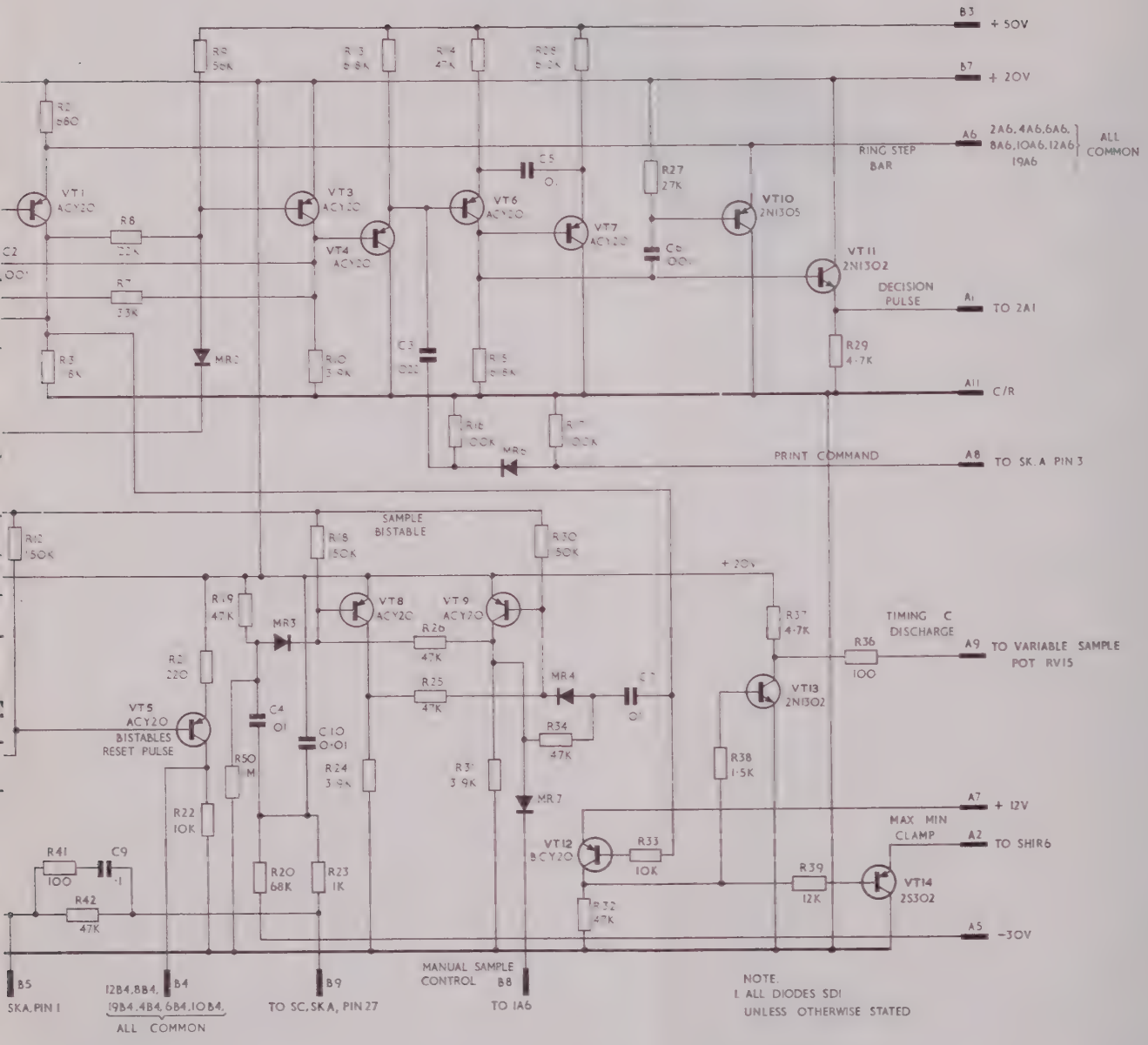

C/R
21
VT1
2N3440
TO 1LP8
10
VT2
A1778
TO 1LP9
11
TO 4A2
12
TO 4A4
13
TO 6B10
14
TO 6A2
15
TO 6A4
16
MR7
MR1
TO 8B8
18
TO 5A9
17



NOTE
1. UNLESS OTHERWISE STATED ALL DIODES SD1

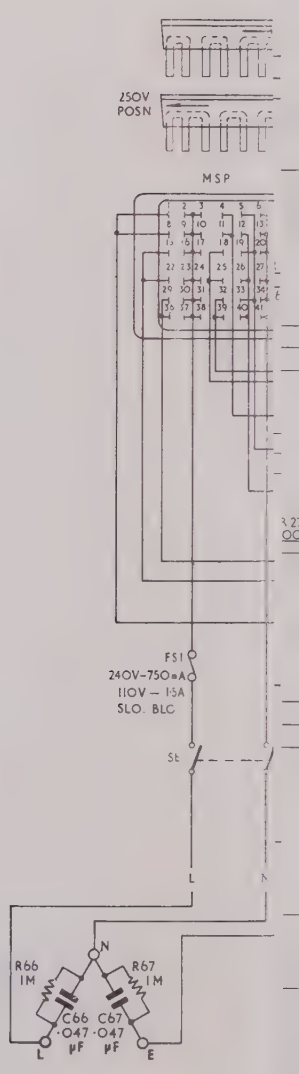
CONTROL CIRCUIT P.C. BOARD 18 C 18679318

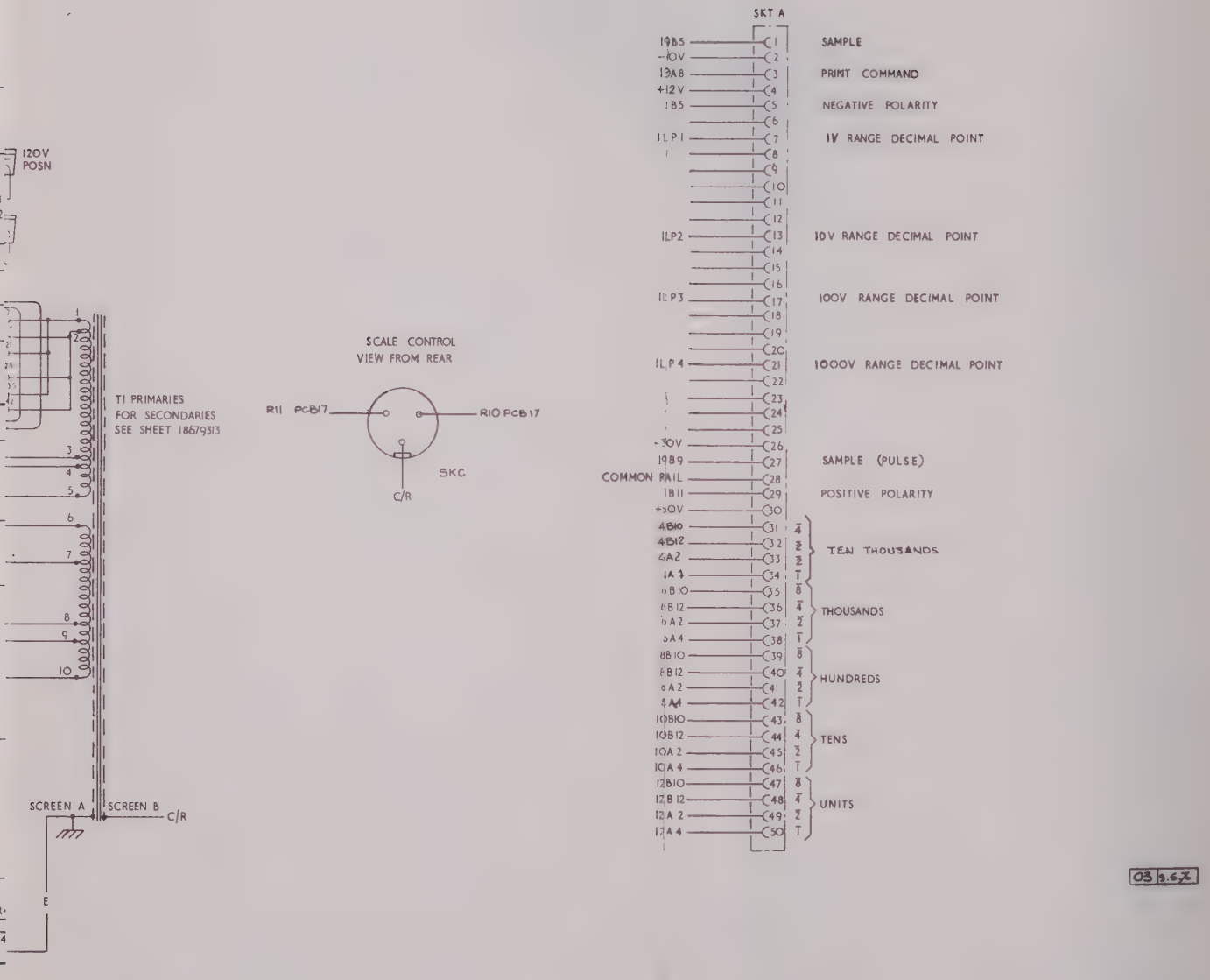

TO 2A4
A4
RING START
MR1
TO12A12
A12 RING RESET
R1 1·5K
C1 ·022
TO 1A2
B1 RING START CONTROL
+50V
B3
R4 150K
VT2 ACY20
R11 15K
R5 47K
R6 47K
R40 47K
C/R
RESET CONTROL
A3
TO 2A3
TO SC



BOARD 19
RING CONTROL RESET & SAMPLE

C 18679319

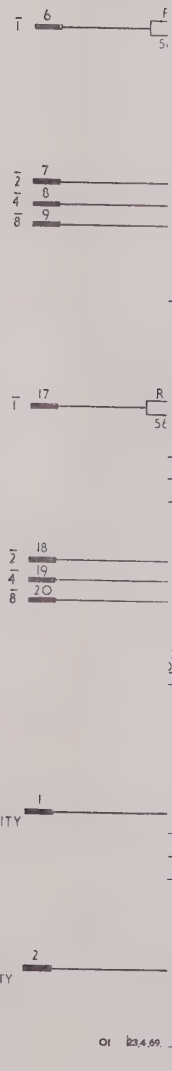

250V
POSN
MSP
FS1
240V-750mA
110V — 1·5A
SLO. BLO
S1
L
N
R66
1M
R67
1M
C66
·047
μF
C67
·047
μF
L
E

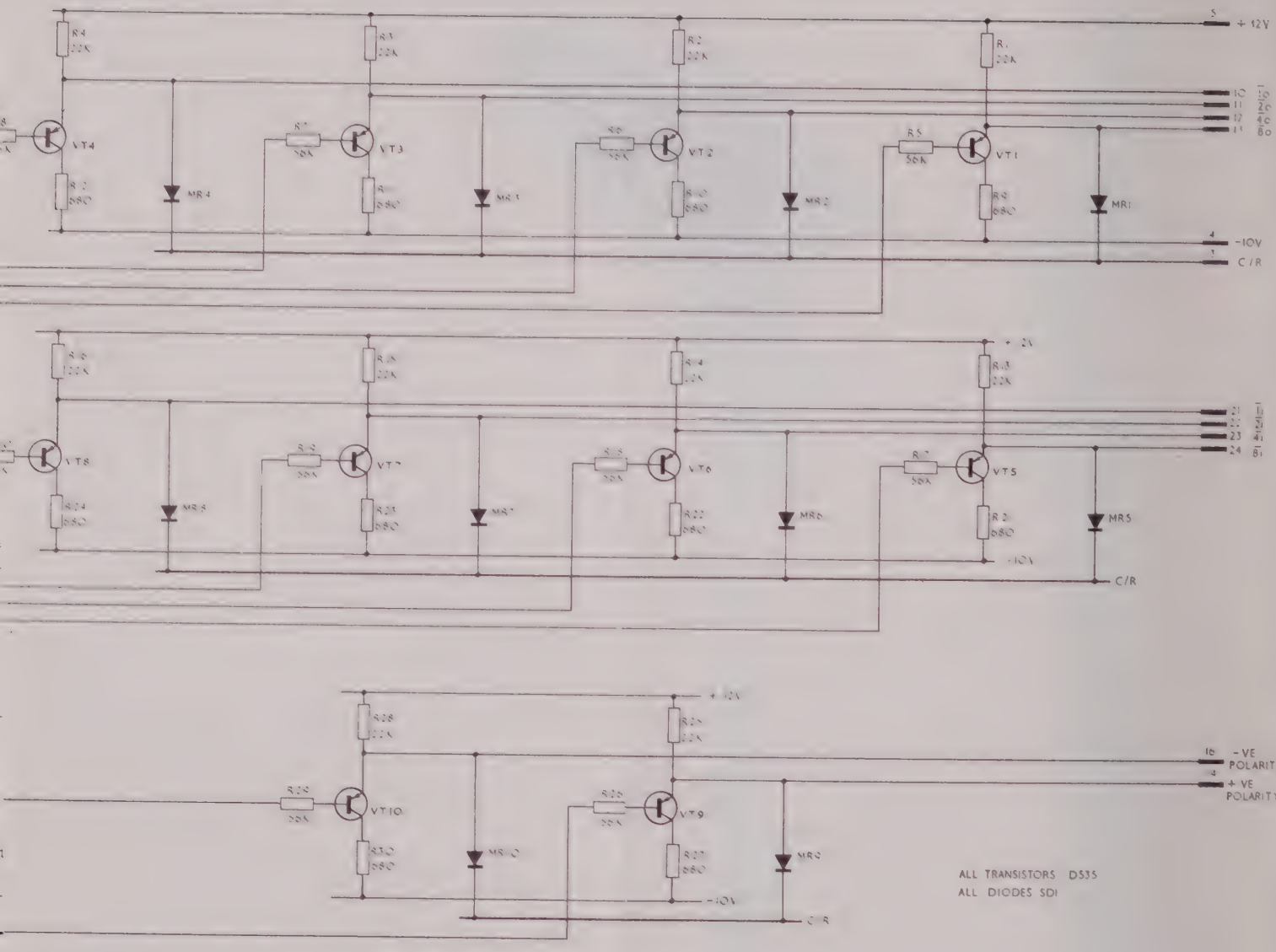


03 9.67

MAINS I/P, TRANSFORMER PRIMARIES,
REAR PANEL SOCKET CONNECTIONS

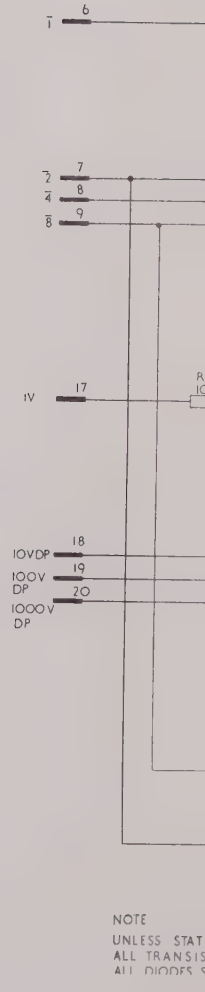
DRAWING NUMBER
C.18677000


1
6
2
7
4
8
8
9
1
17
2
18
4
19
8
20
-VE POLARITY
1
+ VE POLARITY
2



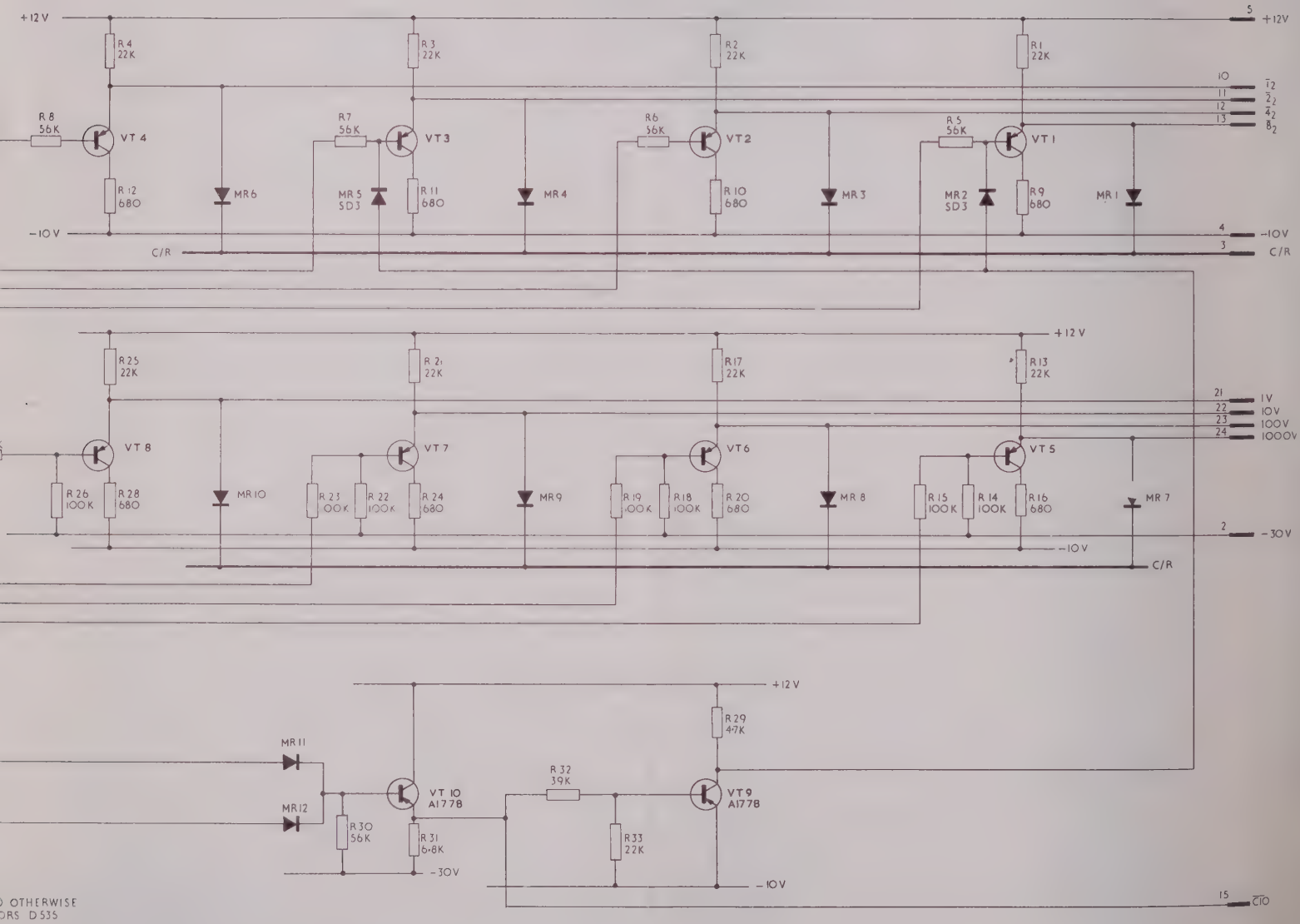
BOARD 1 10^0 & 10^1 DECADE & POLARITY

DRAWING NUMBER
C1869930I



NOTE

UNLESS STAT
ALL TRANSIS
ALL DIODES



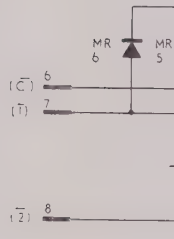
) OTHERWISE
ORS D535

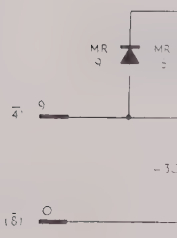
01 23.4.69

DRAWING NUMBER

C 18699302

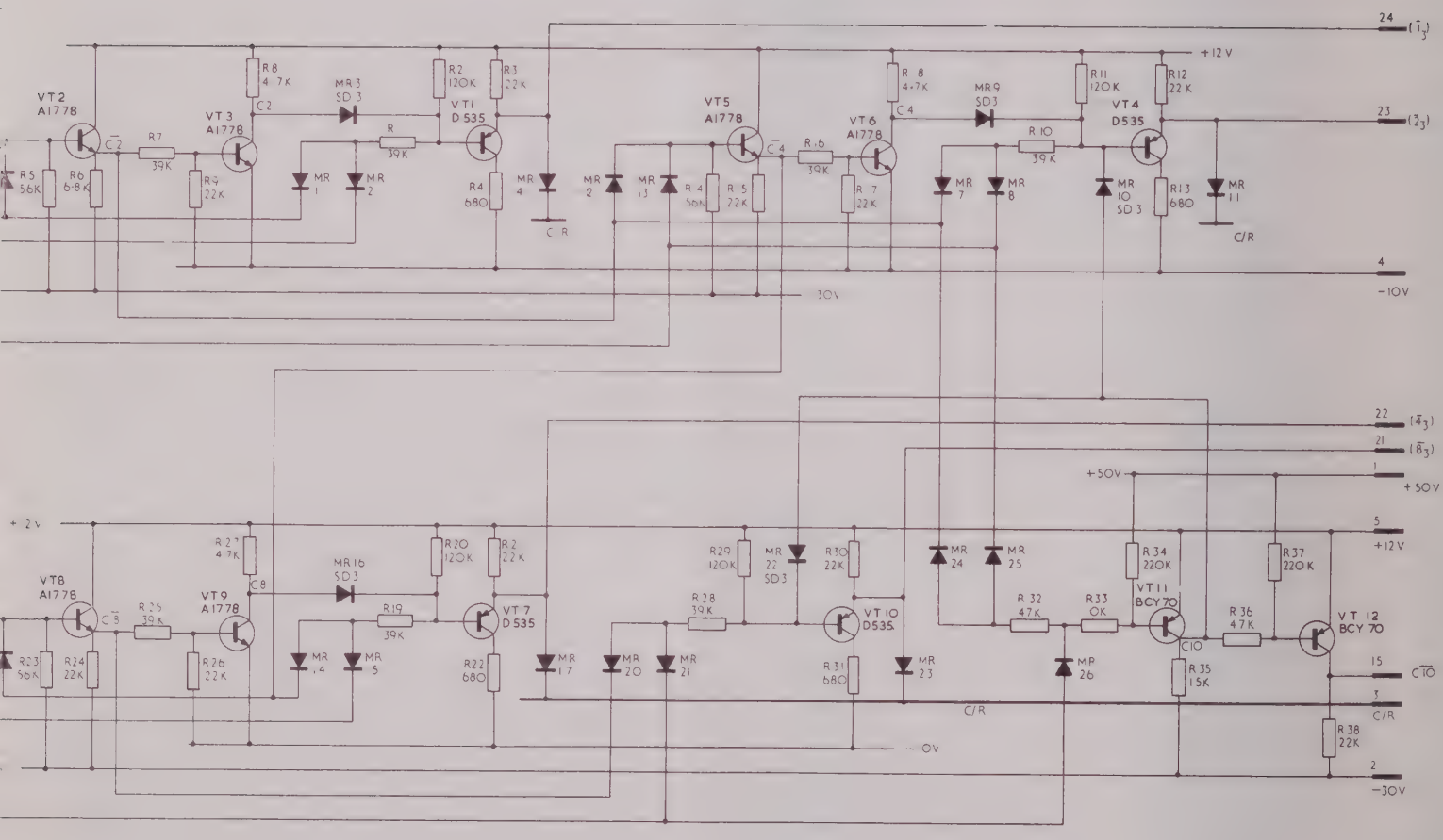
BOARD 2 (RANGE & 10^2 DECADE)





NOTE

UNLESS OTHER
ALL DIODES

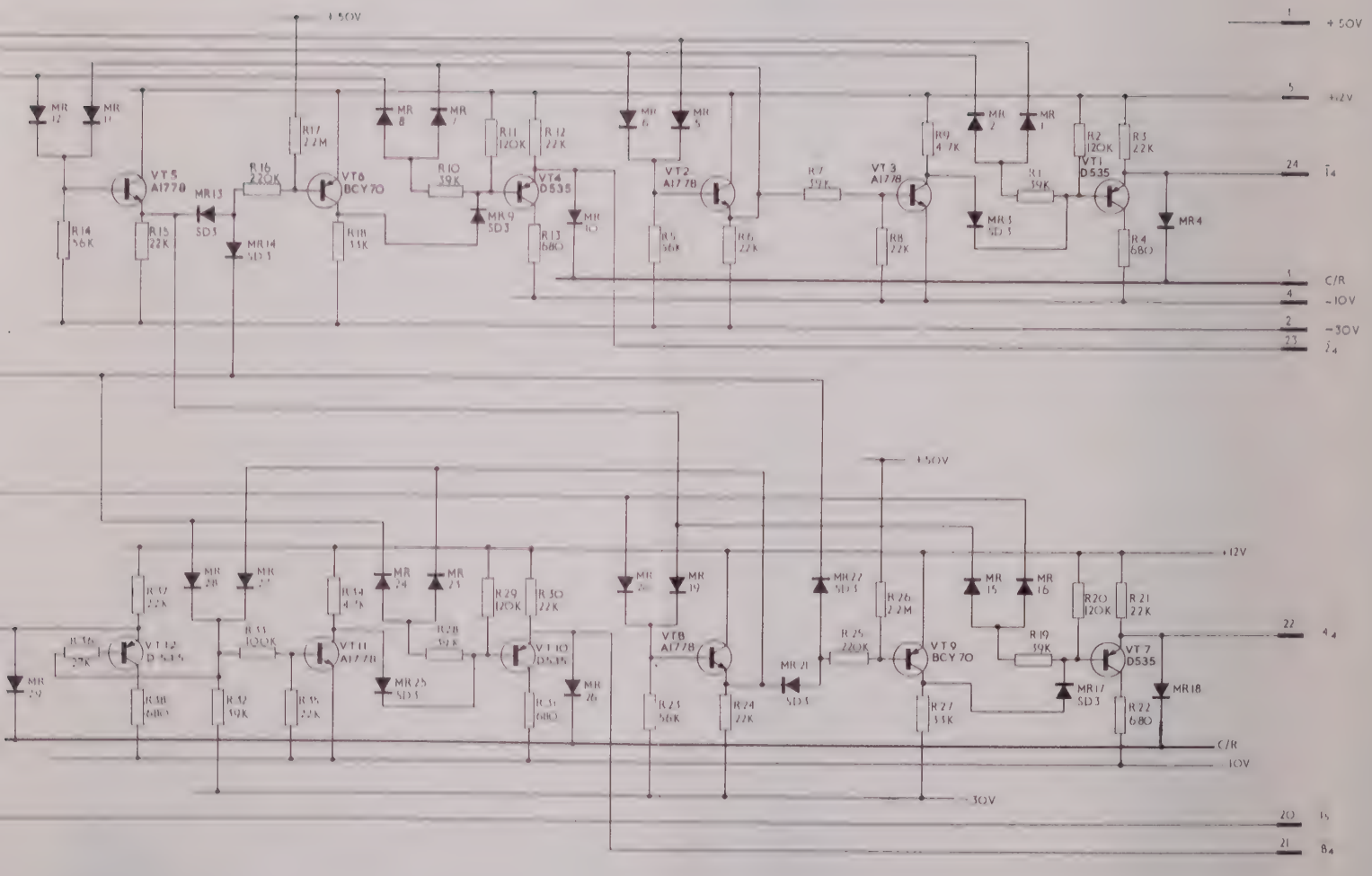


WISE STATED
D1

01 23 45

10^3 DECADE BOARD 3

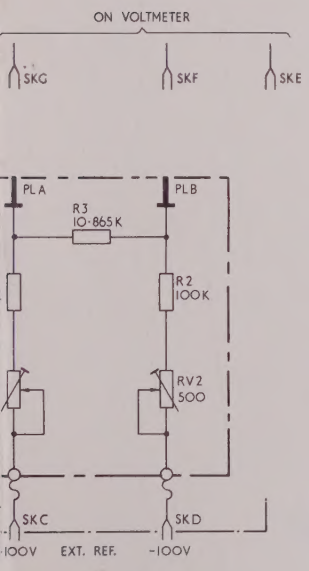
DRAWING NUMBER
C 18699303



UNLESS OTHERWISE STATED

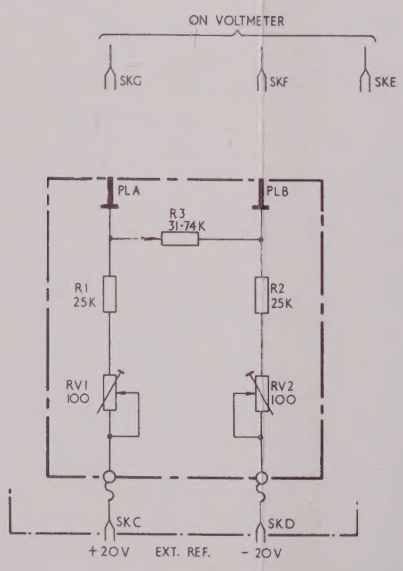
BOARD 4 10^4 AND 10^5 DECADE

DRAWING NUMBER
C 18699304



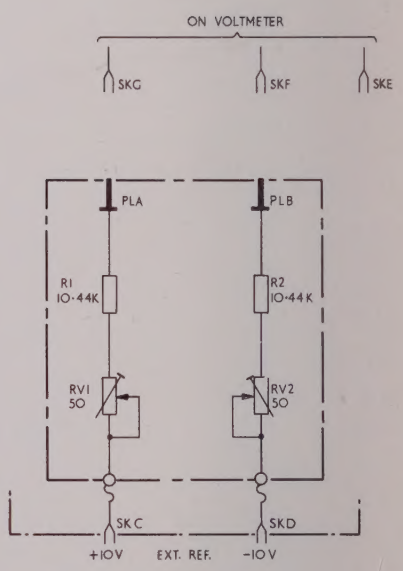
EXT REF

DRAWING NUMBER
A 16269301



EX 1627±20V EXT REF
UNIT

DRAWING NUMBER
A 16279301



01A

EX 1628± 10V EXT. REF
UNIT

DRAWING NUMBER
A 16289301

SOLARTRON

A Schlumberger Company

THE SOLARTRON ELECTRONIC GROUP LTD. FARNBOROUGH · HAMPSHIRE · ENGLAND